

BioNLI: Generating a Biomedical NLI Dataset Using Lexico-semantic Constraints for Adversarial Examples

Findings at EMNLP 2022





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Biomedical NLP



> Cell. 2022 Nov 2;85(9):8742-8742(10)3939-9. doi: 10.1016/j.cell.2022.10.077. Online ahead of print.

The phenotypic landscape of essential human genes

Luke Funk ¹, Kuan-Chung Su ², Jimmy Ly ³, David Feldman ⁴, Anar Singh ⁵, Brittanja Moodie ⁶,
Shaun Strimling ⁷, Dan M. Cline ⁸

Affiliations + expand
PMID: 36347254 DOI: 10.1016/j.cell.2022.10.077

Abstract

Distinct Gene Expression Profiles in Viable Hepatocellular Carcinoma Treated With Liver-Directed Therapy

Understanding the basis for differential gene expression and transcriptional regulation and transcriptional control in liver cancer is essential for the development of novel therapies. We performed a genome-wide screen of 8,072 genes for their ability to regulate gene expression in liver cancer. We identified 1,000 genes that are differentially expressed in liver cancer and identified 100 genes that are differentially expressed in liver cancer.

Affiliations + expand
PMID: 35781074 PMID: 360248864 DOI: 10.3389/fonc.2022.809860

Abstract

Diagnosis and Treatment of Leishmaniasis: Clinical Practice Guidelines by the Infectious Diseases Society of America (IDSA) and the American Society of Tropical Medicine and Hygiene (ASTMH)

Naomi Aronson ¹, Barbara L. Herwaldt ², Michael Libman ³, Richard Pearson ⁴,
Stephanie Lopez-Velez ⁵, Peter Hens ⁶, Roger M Cavalcanti ⁷, Melissa Espinoza ⁸, Susana Jacovino ⁹,
Alan Maggi ¹⁰

Affiliations + expand
PMID: 37141953 DOI: 10.1093/cid/ciab270

Abstract

Synergistic Protection against Secondary Pneumococcal Infection by Human Monoclonal Antibodies Targeting Distinct Epitopes

Aaron D. Singer ¹, Frederick Royer ¹, Anita L. McCormick ^{1, 2}, Anna Scasny ³, Jorge E. Valde ⁴,
Jared J. Mazuski ^{4, 5, 6}

Affiliations + expand
PMID: 37141953 DOI: 10.1093/cid/ciab270

Empagliflozin in Patients with Chronic Kidney Disease

EMPA-KIDNEY Collaborative Group, William D. Hemington ¹, Natalie Sleight ², Christoph Wanner ³,
Jennifer E. Dean ⁴, Shihui J. Heussen ⁵, Jonathan R. Eshkol ⁶, David Preiss ⁷,
Parvinder Judge ⁸, Kaitlin J. Myers ⁹, Sarah Y. A. Ng ¹⁰, Emily Sammons ¹¹, Dorren Zhu ¹²,
Michael Hall ¹³, Yifeng Chen ¹⁴, Kari Valtonen ¹⁵, Susanna Benes ¹⁶, Alfred C. Cheng ¹⁷,
Zhi-Hong Liu ¹⁸, Jing Li ¹⁹, Lei Song ²⁰, Wen Liu ²¹, Takashi Kodama ²², Masami Nangaku ²³,
Adrian Lewis ²⁴, David Cherny ²⁵, Aiko Nakagawa ²⁶, Roberto Pecherini ²⁷, David Cook ²⁸,
Shinya Otsu ²⁹, Xavier Rossato ³⁰, Katherine R. Little ³¹, Dominik Studer ³², Michele Perrini ³³,
Dan Heuser ³⁴, Jeroen Eekhout ³⁵, Martina Buechtemann ³⁶, Martin J. Landray ³⁷, Colin Baggett ³⁸,
Richard Murray ³⁹

Affiliations + expand
PMID: 36337160 DOI: 10.1016/j.neur.2022.04.023

Background: The effects of empagliflozin in patients with chronic kidney disease who are at risk for disease progression are not well understood. The EMPA-KIDNEY trial was designed to assess the effects of treatment with empagliflozin in a broad range of such patients.
Methods: We enrolled patients with chronic kidney disease who had an estimated glomerular filtration rate (eGFR) of at least 20 but less than 45 ml per minute per 1.73 m² of body-surface area,

with respect to particular
homocysteine to these guidelines
to be made to the

interleukin-6 despite the
and serotype coverage of current
type, as well as an increase in
infection often follows a primary viral
and results in bacterial spread to the
lignified the covered surface. Ag
estimated that makes to this. Ag are
Stably and immunoprecipitable in this study.
re-pneumococcal human mAb, PHO3,
vaptans in a mouse model of

> 1M publications per year

Reasoning about Biomedical Mechanisms

1. In order to ... the mechanism of gonadotropin action on steroid ... in vitro.
2. The addition of 25-hydroxy cholesterol, ... increased ... in a dose-dependent manner.
3. Inhibition of cholesterol side-chain cleavage ... blocked ... cholesterol-promoted steroid accumulation ..., indicating that 25-hydroxy cholesterol ... is metabolized ... to an active steroid
4. Likewise, trilostane, an inhibitor of delta 5-3 beta-hydroxysteroid dehydrogenase, blocked pregnenolone action.
5. ...

We have concluded from these observations that cholesterol side-chain cleavage and ... are essential for ... steroid production ... and gonadotropin initiates steroid by acting at a step prior to the conversion of cholesterol to ...

- Publications study and report on mechanisms underlying relations
- It's crucial to infer these mechanisms from evidence
- We need systems that can validate whether a given mechanism can be inferred from some evidence
- We need resources to train these systems

Manual Data Creation



Manual Data Creation



- Need Expert Knowledge

Manual Data Creation



- Need Expert Knowledge
- Time Consuming

Manual Data Creation



- Need Expert Knowledge
- Time Consuming
- Expensive

Manual Data Creation



- Need Expert Knowledge
- Time Consuming
- Expensive
- Human bias

Related Work

- MedNLI (Romanov and Shivade, 2018)



Related Work



- MedNLI (Romanov and Shivade, 2018)
- SciTail (Khot et al., 2018)

Related Work



- MedNLI (Romanov and Shivade, 2018)
- SciTail (Khot et al., 2018)
- Clinical Trial Inference (Shivade et al., 2015)

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- MedNLI (Romanov and Shivade, 2018)
- SciTail (Khot et al., 2018)
- Clinical Trial Inference (Shivade et al., 2015)
- Health Care Entailment (Adler et al., 2012)

SuMe: Summarizing Biomedical Mechanism Dataset

Given:

Set of sentences (supporting set)

Pair of entities

1. In order to ... the mechanism of gonadotropin action on steroid ... in vitro.
2. The addition of 25-hydroxy cholesterol, ... increased ... in a dose-dependent manner.
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5. ...

Generate:

Relation that connects the entities

Sentence explaining the mechanism



We have concluded from these observations that cholesterol side-chain cleavage and ... are essential for ... steroid production ... and gonadotropin initiates steroid by acting at a step prior to the conversion of cholesterol to ...

Task Definition: Biomedical NLI

1. In order to ... the mechanism of gonadotropin action on steroid ... in vitro.
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We have concluded from these observations that cholesterol side-chain cleavage and ... are essential for ... steroid production ... and gonadotropin initiates steroid by acting at a step prior to the conversion of cholesterol to ...

Entailed



Not entailed

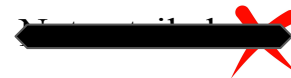


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Entailed



How to generate adversarial examples from positive ones?

1. In order to ... the mechanism of gonadotropin action on steroid ... in vitro.
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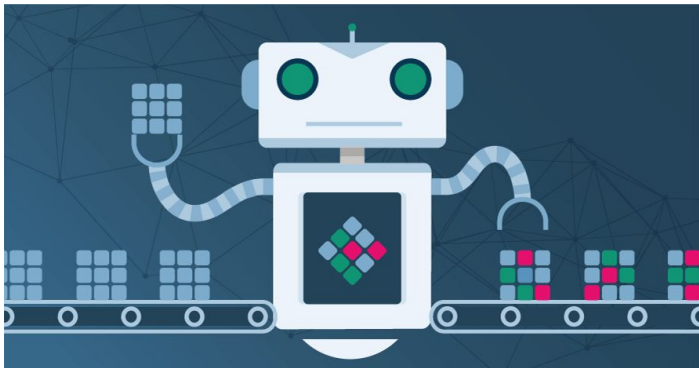


We have concluded from these observations that cholesterol side-chain cleavage and ... are essential for ... steroid production ... and gonadotropin initiates steroid by acting at a step prior to the conversion of cholesterol to ...



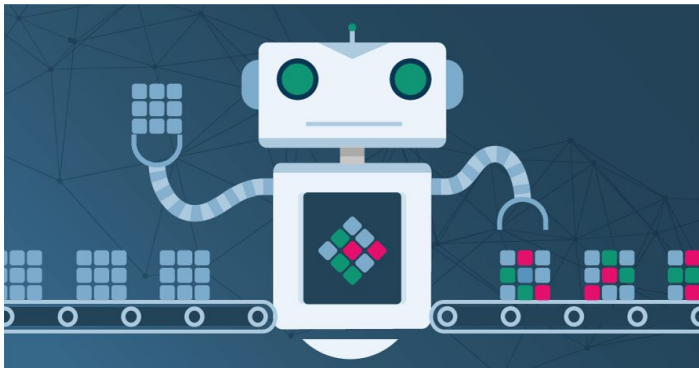
We have concluded from these observations that vasodilation side-chain cleavage and ... are essential for ... gonadotropin-promoted follicle steroid production ... and gonadotropin initiates steroid by acting at a step prior to the conversion of vasodilation to ...

Automatic adversarial generation challenges



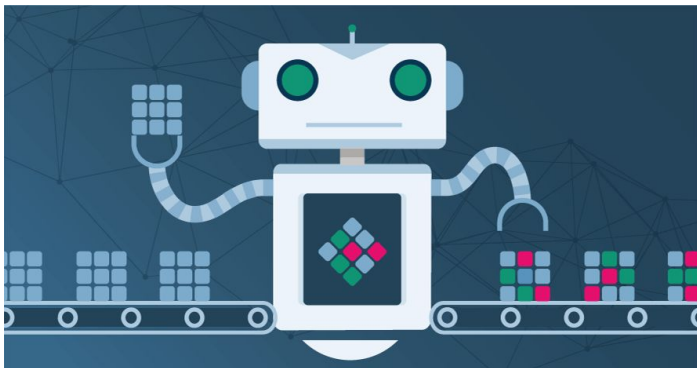
- Easy-to-predict samples

Automatic adversarial generation challenges



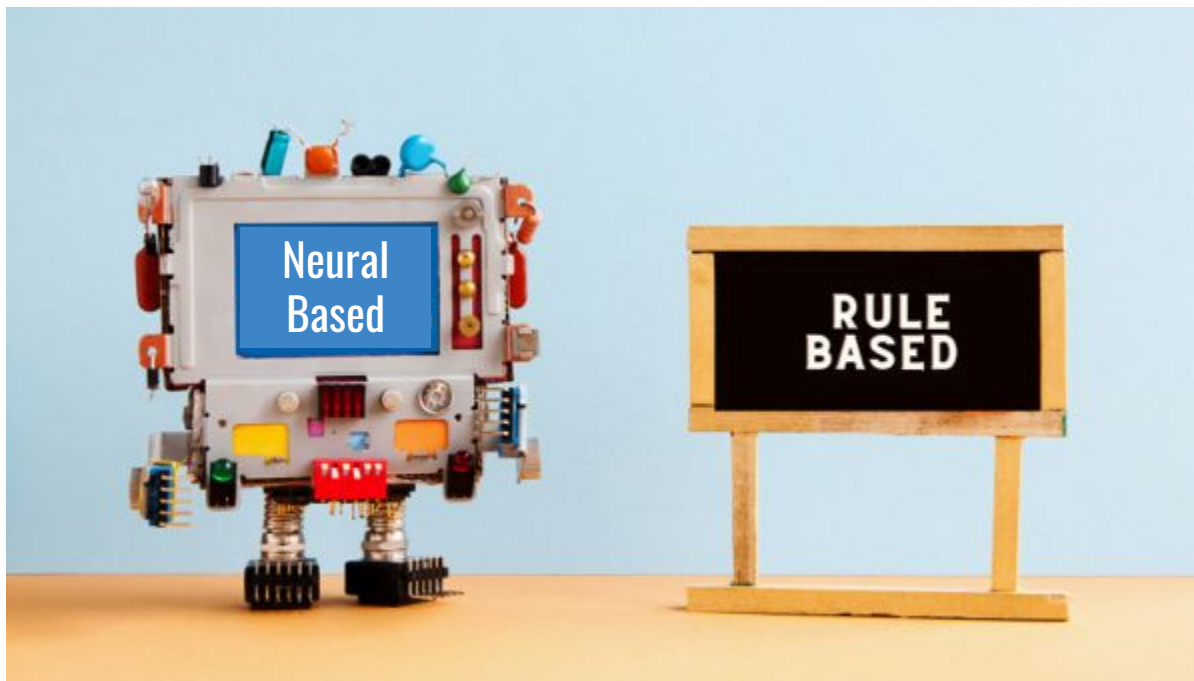
- Easy-to-predict samples
- Incorrect samples

Automatic adversarial generation challenges



- Easy-to-predict samples
- Incorrect samples
- Defining constraints

How to generate adversarial examples from positive ones?



What kind of transformations can yield negatives?

Simple transformations: swap entity names

We have concluded from these observations that cholesterol side-chain cleavage and ... are essential for ... steroid production ... the enzymes necessary for the conversion of cholesterol to 17 alpha-OH ... and gonadotropin initiates steroid by acting at a step prior to the conversion of cholesterol to ...

REG	ELE
cholesterol	steroid

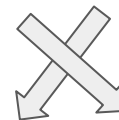
Simple transformations: swap entity names

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REG	ELE
cholesterol	steroid



REG	ELE
steroid	cholesterol

Simple transformations: verb negation

We have concluded from these observations that cholesterol side-chain cleavage and ... are essential for ... steroid production ... the enzymes necessary for the conversion of cholesterol to 17 alpha-OH ... and gonadotropin initiates steroid by acting at a step prior to the conversion of cholesterol to ...



We have concluded from these observations that cholesterol side-chain cleavage and ... are not essential for ... steroid production ... the enzymes necessary for the conversion of cholesterol to 17 alpha-OH ... and gonadotropin initiates steroid by acting at a step prior to the conversion of cholesterol to ...

VERB

are essential



VERB

are not essential

Simple transformations: swap numbers

We have concluded from these observations that cholesterol side-chain cleavage and ... are essential for ... steroid production ... the enzymes necessary for the conversion of cholesterol to 17 alpha-OH ... and gonadotropin initiates steroid by acting at a step prior to the conversion of cholesterol to ...



We have concluded from these observations that cholesterol side-chain cleavage and ... are essential for ... steroid production ... the enzymes necessary for the conversion of cholesterol to 25 alpha-OH ... and gonadotropin initiates steroid by acting at a step prior to the conversion of cholesterol to ...

NUMBER

17



NUMBER

25

Rule-based Transformations

1. Swap entity names (SEN)
2. Swap entity positions (SEP)
3. Swap random entity (SRE)
4. Swap random entity with out of text entity (SREO)
5. Verb negation (VN)
6. Swap numbers (SN)
7. Lexical Polarity Reversal (LPR)

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Pros:

- Easy to create.

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- Semantics are clear

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Pros:

- Easy to create.
- Semantics are clear

Cons:

- Easy for models
- Number and type of samples is limited

Generation-based Methods

Abstract

1. In order to ... the mechanism of gonadotropin action on steroid ... in vitro.
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T5

Generation-based Methods

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5. ...

T5

Generated Output

We have concluded from these observations that cholesterol side-chain ...

It can be concluded that cholesterol-promoted steroid accumulation ...

In conclusion, 25-hydroxycholesterol is ...

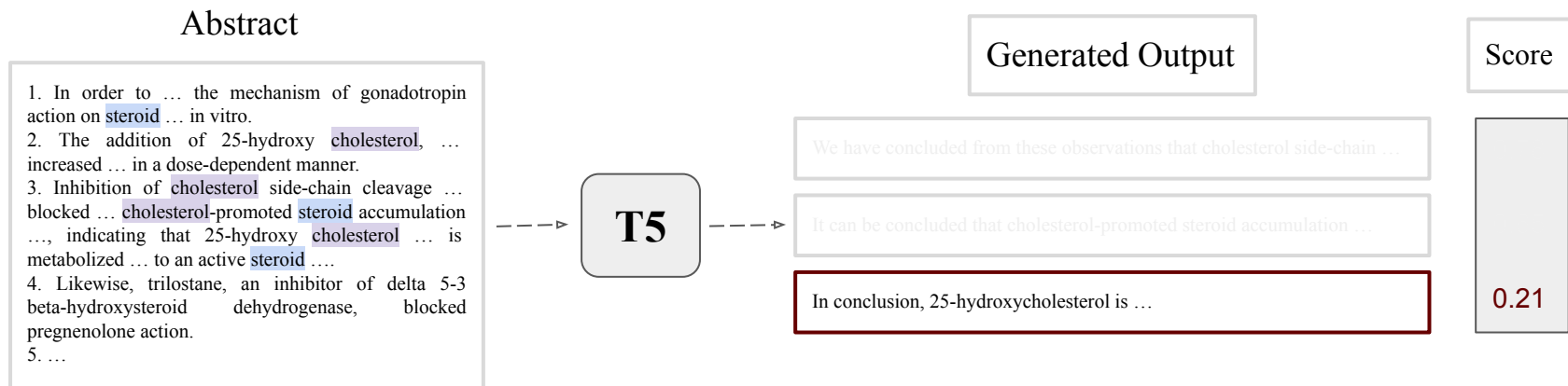
Score

0.78

0.65

0.21

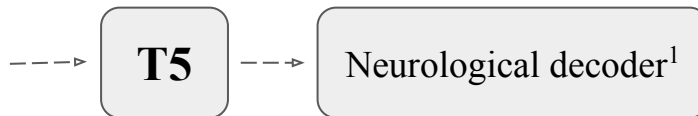
Generation-based Methods



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T5

Neurological decoder¹

SEN constraints:
steroid is REG and
cholesterol is ELE

We conclude that steroid is ...

Generation-based Methods

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5. ...

T5

Neurological decoder¹

SRE constraints:
cholesterol is REG and
GVBD is ELE

In conclusion GVBD is regulated by ...

Generation-based Methods

Abstract

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T5

Neurological decoder¹

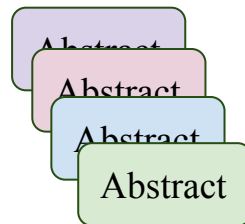
Negative constraints:
cholesterol is not REG and
steroid is not ELE

We conclude that ...

The BioNLI Dataset



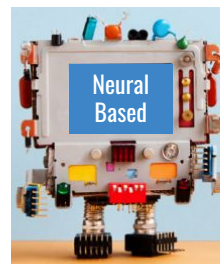
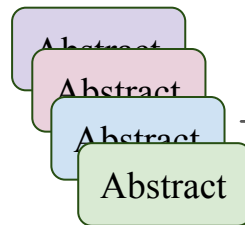
Extract
Mechanisms



The BioNLI Dataset



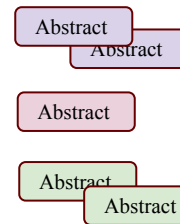
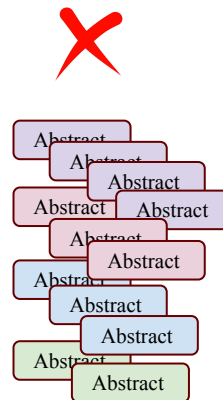
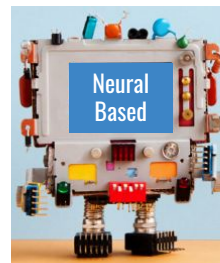
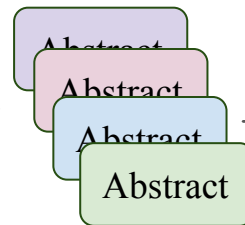
Extract
Mechanisms



The BioNLI Dataset



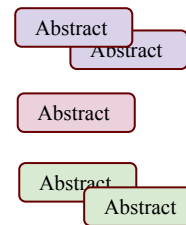
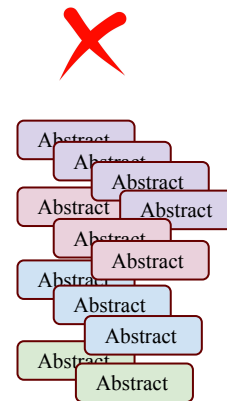
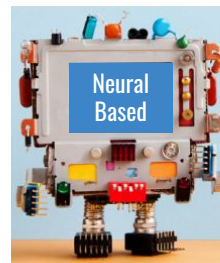
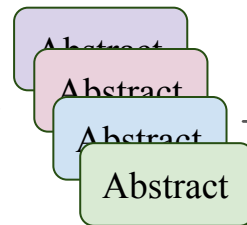
Extract Mechanisms



The BioNLI Dataset



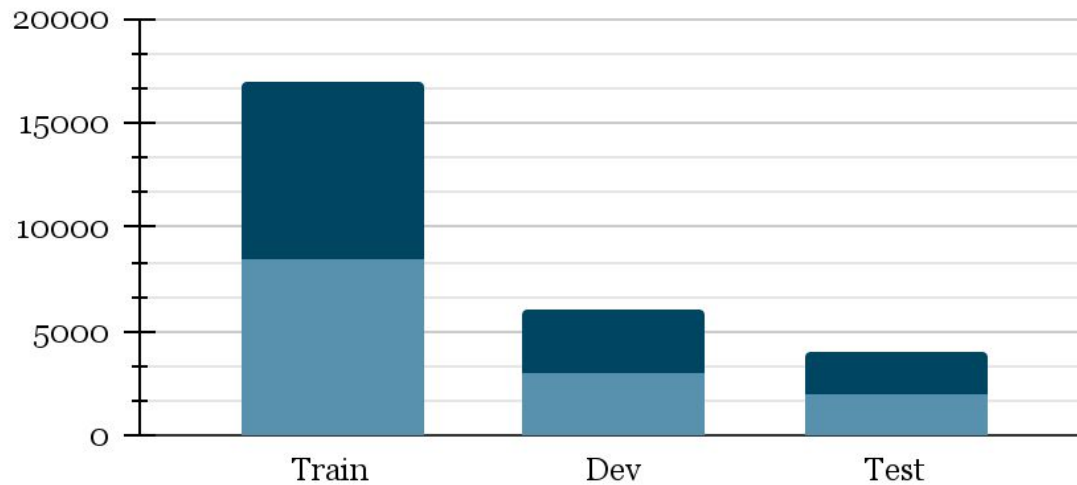
Extract Mechanisms



Data Statistics: Full distribution

Data Distribution (unique)

■ Positive ■ Negative

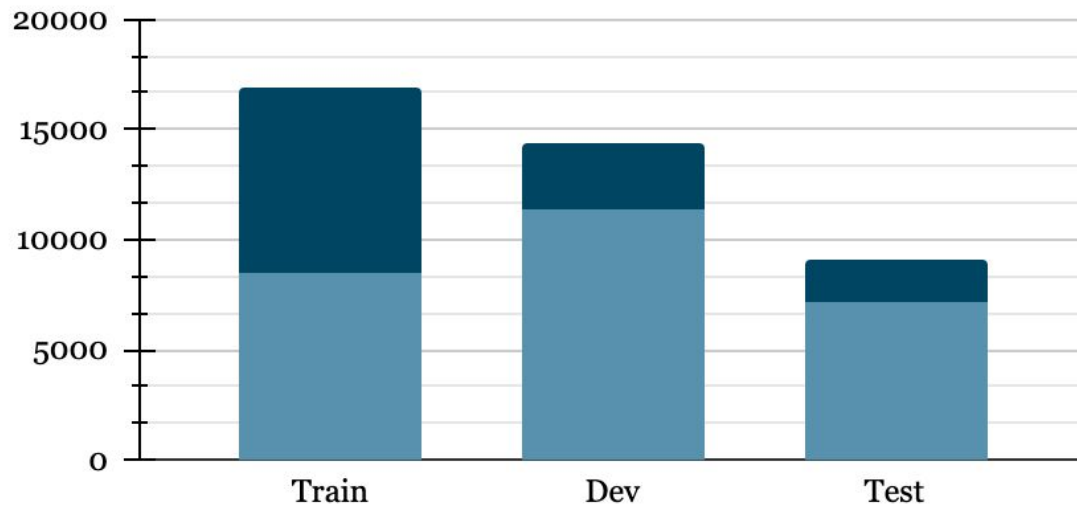


- More than 21K instances in total
- Roughly balanced positive and unique negative instances.

Data Statistics: Full distribution

Data Distribution

■ Positive ■ Negative

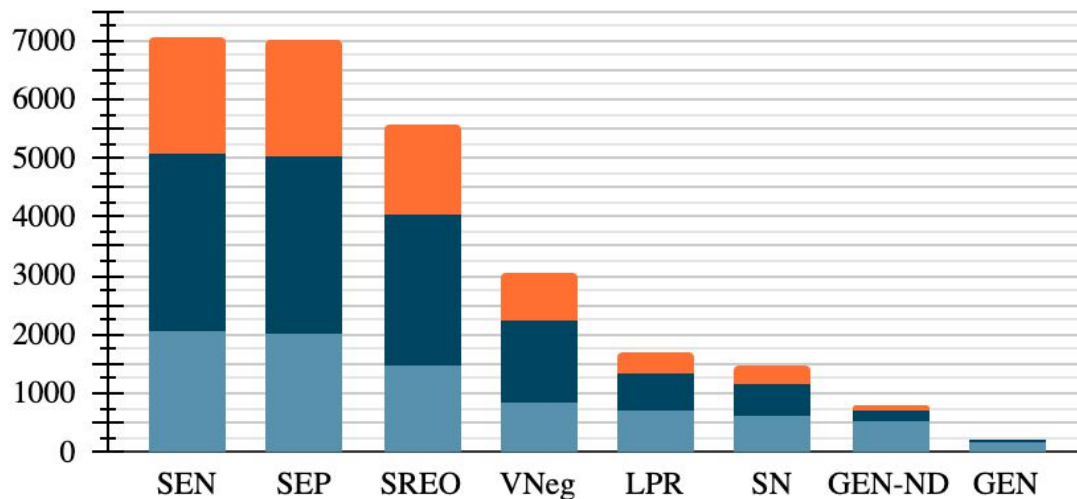


- Generating all possible perturbations for each instance

Data Statistics: Full distribution

Full Distribution

Test Dev Train



- ❑ Generating all possible perturbations for each instance
- ❑ Imbalanced categorical data in negative instances

Benchmarking Evaluation

Benchmarking Evaluation

- How well do existing Biomedical LMs fare on this NLI task?

Benchmarking Evaluation

- How well do existing Biomedical LMs fare on this NLI task?

LMs: PubMedBERT, BioLinkBERT

Benchmarking Evaluation

- How well do existing Biomedical LMs fare on this NLI task?

LMs: PubMedBERT, BioLinkBERT

- How is the performance of hypothesis only models?

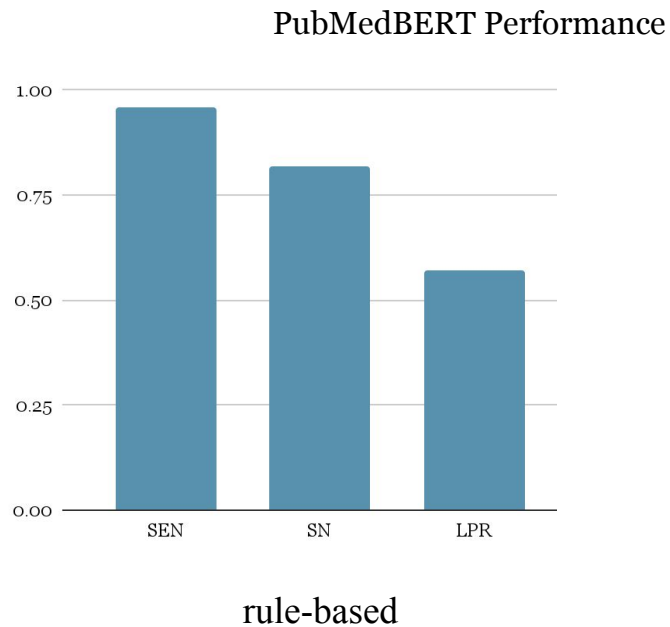
Benchmarking Evaluation

- How well do existing Biomedical LMs fare on this NLI task?

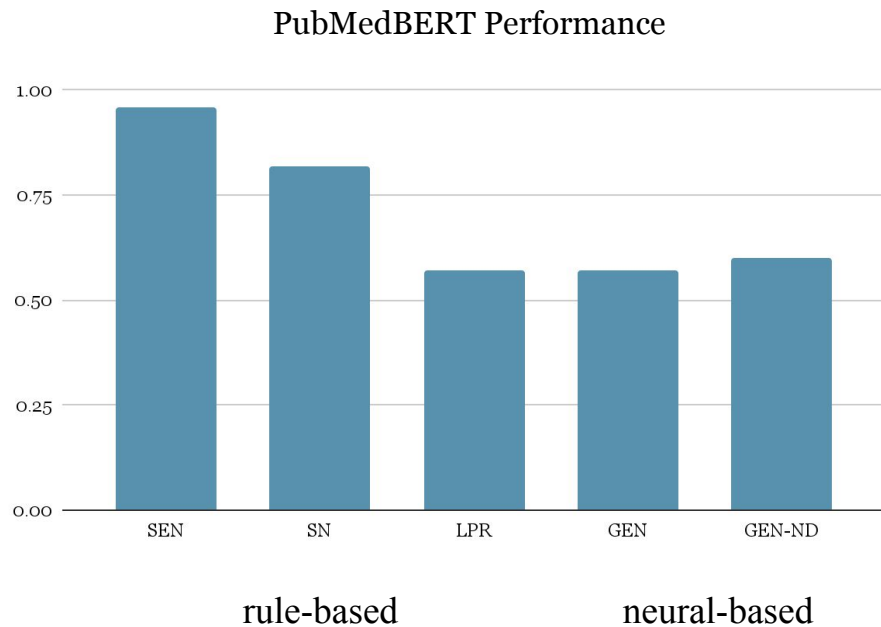
LMs: PubMedBERT, BioLinkBERT

- How is the performance of hypothesis only models?
- Are the LMs consistent over groups of adversarial instances?

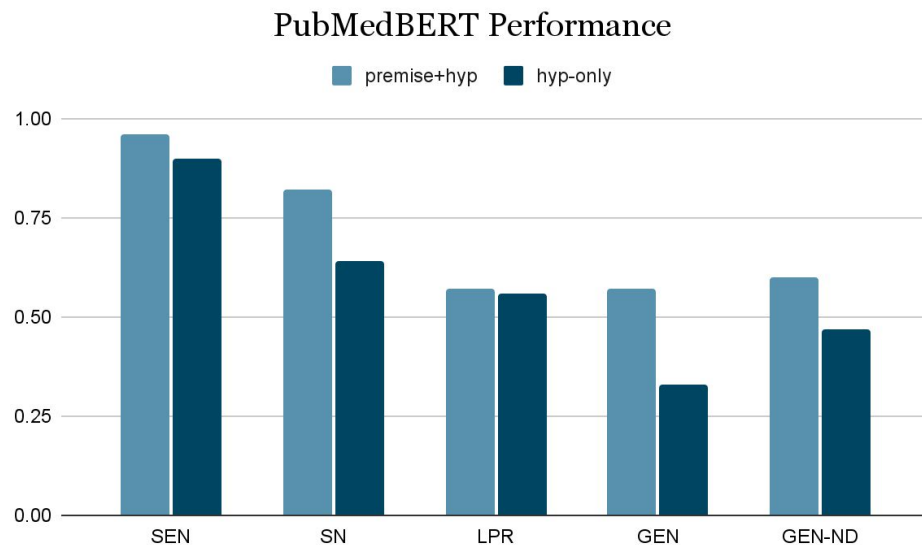
Evaluation: rule-based vs neural-based methods



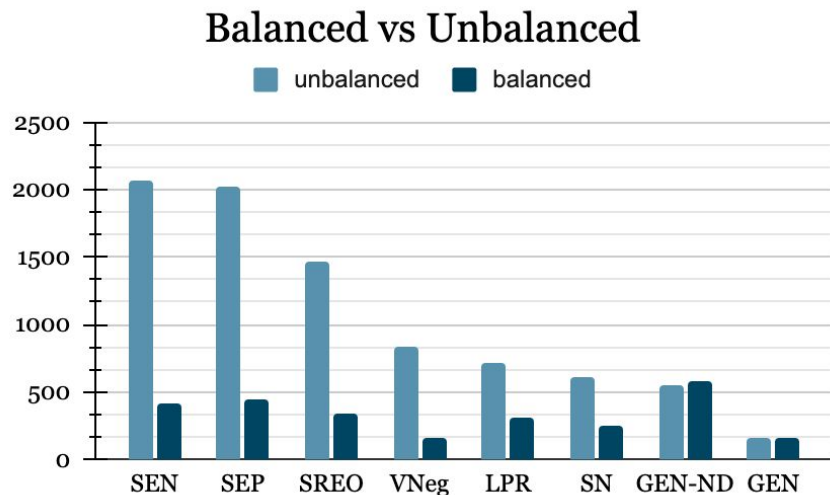
Evaluation: rule-based vs neural-based methods



Evaluation: BioNLI is hard to game with hypothesis only model

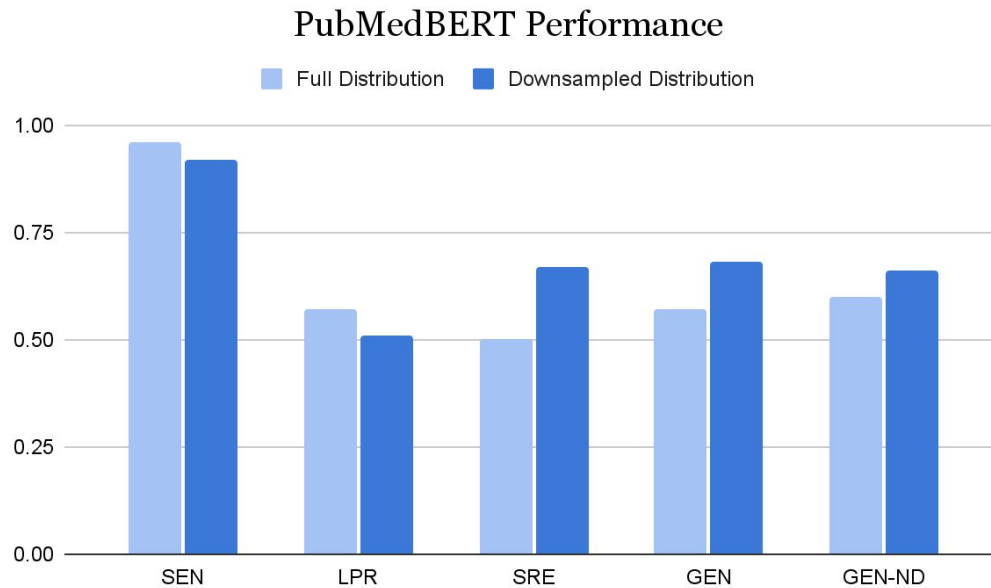


Data Statistics: What is the impact of category distribution?



- Category distributions are unbalanced
- Downsample the dominant categories

Evaluation: Balanced Distribution



Error Analysis

1.	Multiple pieces of information	10%
2.	Abbreviation	10%
3.	Unrelated information	16%
4.	Mechanism mix up	18%
5.	Noun phrase mix up	20%
6.	Entity Similarity	26%

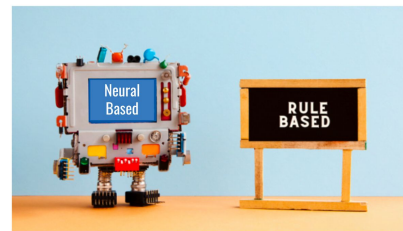
Takeaways

- New Biomedical NLI task based on mechanisms.

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- Automatic methods for high quality NLI instances.



- Challenges for consistent NLI reasoning in LMs.

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3. Unrelated information	16%
4. Mechanism mix up	18%
5. Noun phrase mix up	20%
6. Entity Similarity	26%

How to access



<https://stonybrooknlp.github.io/BioNLI/>



mbastan@cs.stonybrook.edu

View on GitHub 

BioNLI

Biomedical Natural Language Inference Dataset

What is BioNLI?

BioNLI is a biomedical NLI dataset using controllable text generation

This is the official page for the paper [BioNLI: Generating a Biomedical NLI Dataset Using Lexico-semantic Constraints for Adversarial Examples](#), accepted at EMNLP2022 (Findings).

BioNLI is the first dataset in biomedical natural language inference. This dataset contains abstracts from biomedical literature and mechanistic premises generated with nine different strategies.