

<https://www.sesameworkshop.org/what-we-do/sesame-streets-50th-anniversary>



# Self-Supervised Learning

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Hung-yi Lee 李宏毅

死臭酸宅本人

芝麻街



CHIMMY  
CAUL CHANG  
BOTON  
I  
THINK  
I'M  
BRED BOO...

BPON

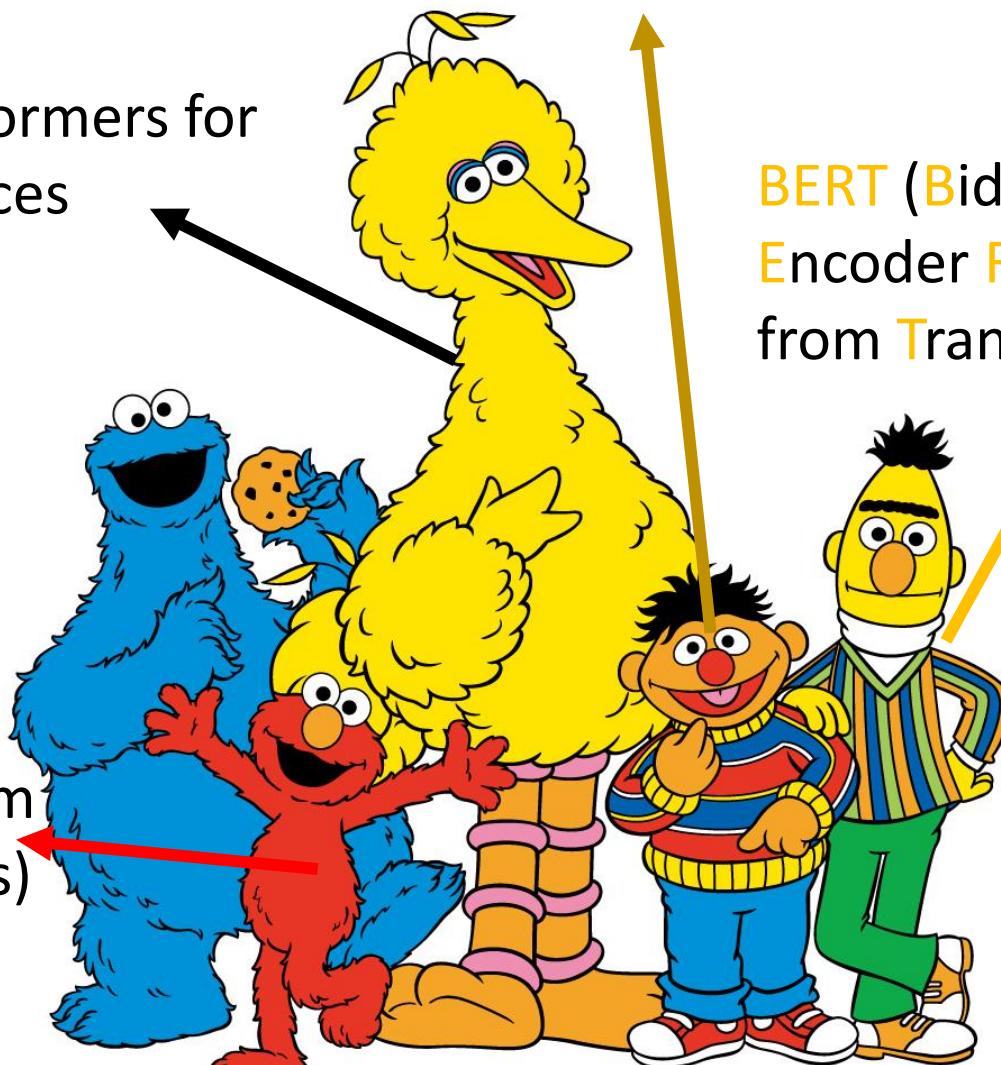
BON

**ERNIE** (Enhanced Representation through Knowledge Integration)

**Big Bird**: Transformers for Longer Sequences

**BERT** (Bidirectional Encoder Representations from Transformers)

**ELMo**  
(Embeddings from Language Models)



**STAYREAL**

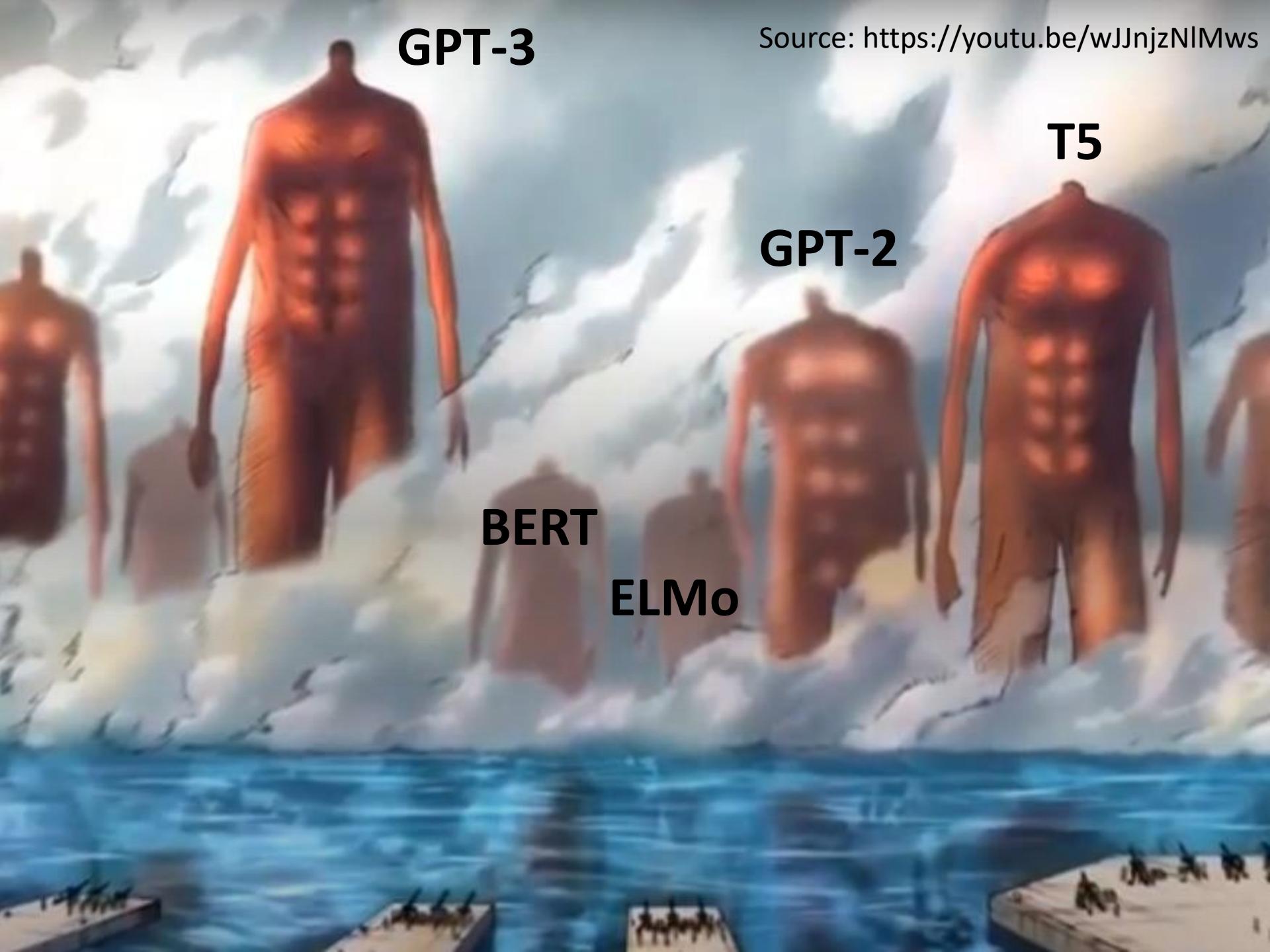


**BERT**  
340M  
parameters

**Bertolt  
Hoover**

Source of image:

[https://leemeng.tw/attack\\_on\\_bert\\_transfer\\_learning\\_in\\_nlp.html](https://leemeng.tw/attack_on_bert_transfer_learning_in_nlp.html)

A painting depicting a group of people standing on large, jagged icebergs floating in a body of water. The figures are rendered in a style that suggests they are made of ice or are melting. The background shows a vast, hazy sky with wispy clouds.

**GPT-3**

Source: <https://youtu.be/wJJnjzNIMws>

**T5**

**GPT-2**

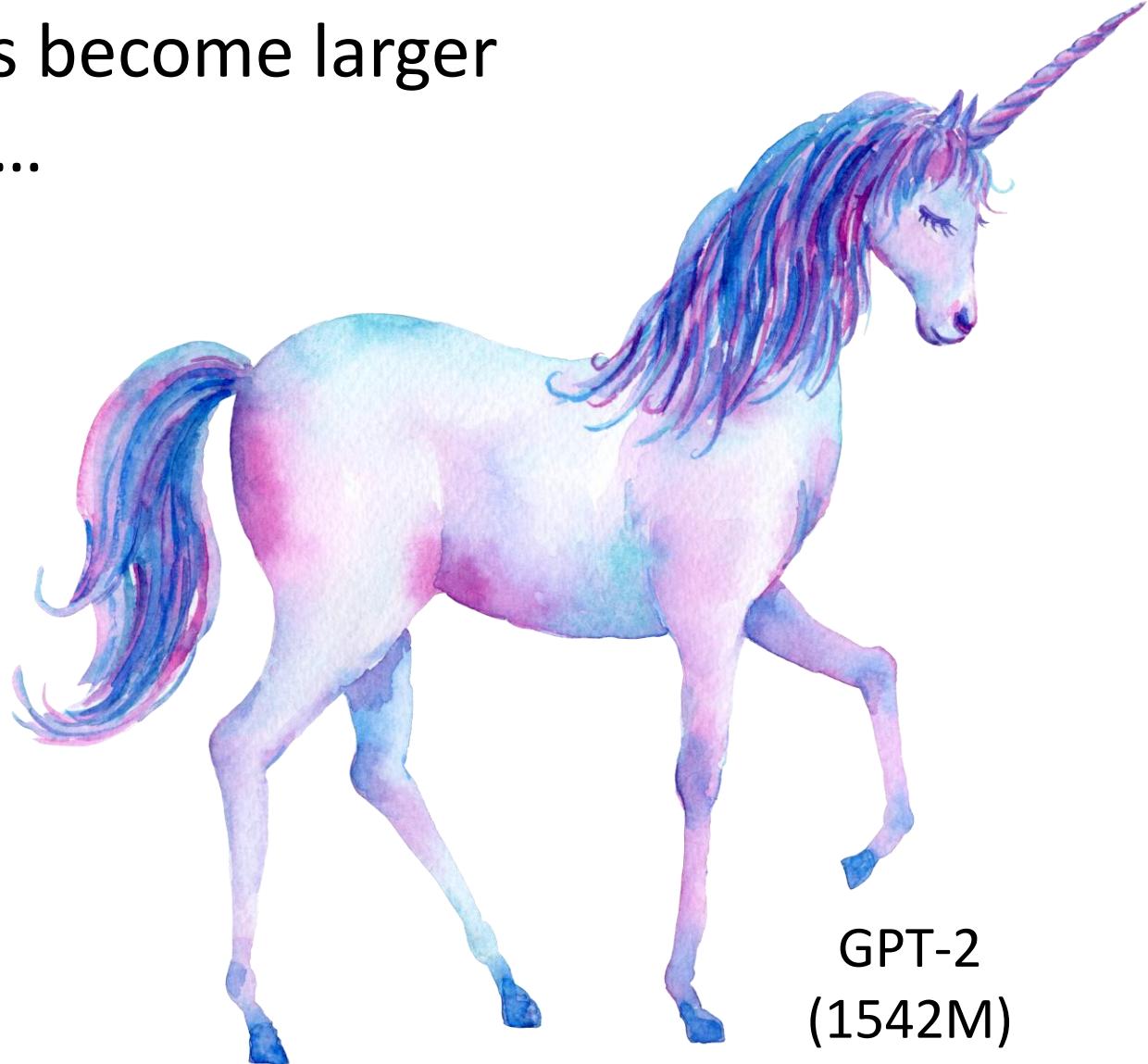
**BERT**

**ELMo**

The models become larger  
and larger ...

BERT  
(340M)

ELMO  
(94M)



Source of image: <https://huaban.com/pins/1714071707/>

The models become larger  
and larger ...

Turing NLG  
(17B)

GPT-3 is **10** times larger than  
Turing NLG.



GPT-2



Megatron (8B)



T5 (11B)



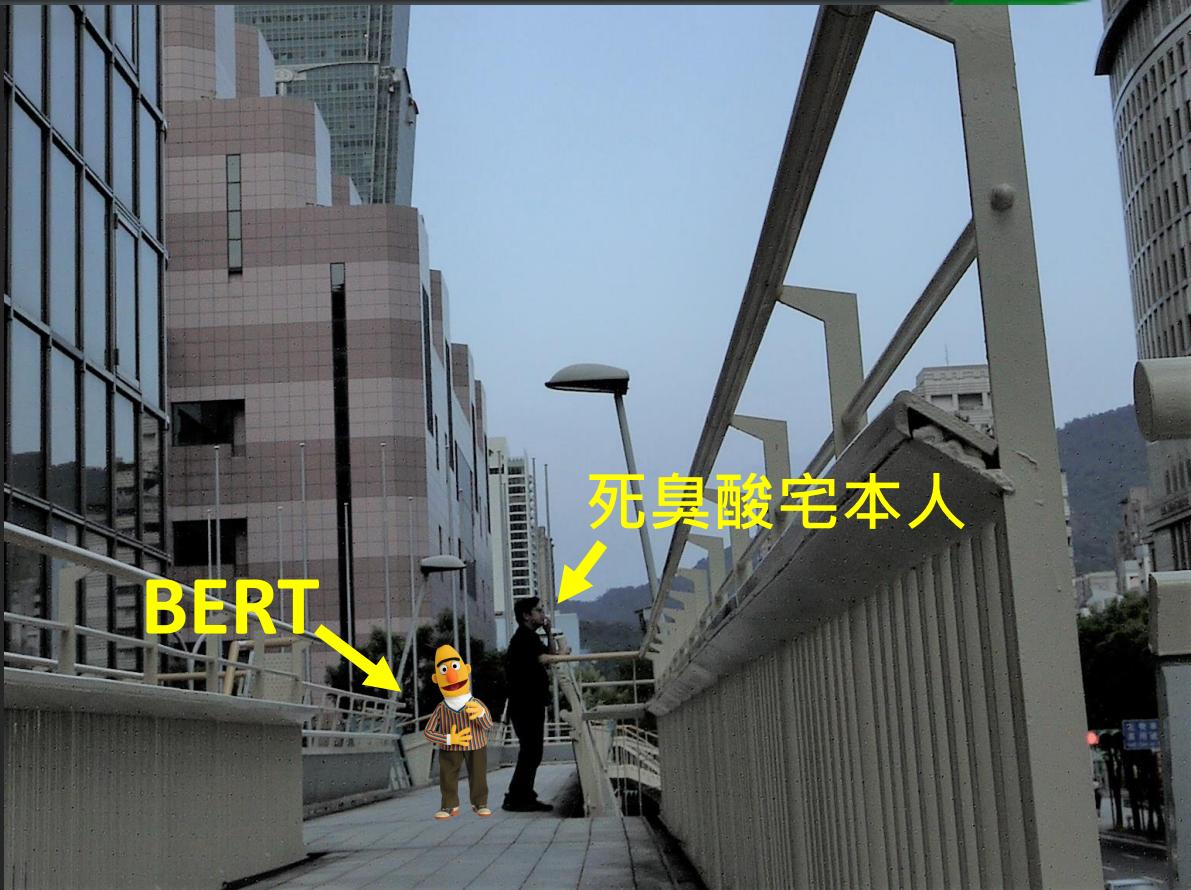


**BERT (340M)**

**GPT-3 (175B)**

**Switch  
Transformer (1.6T)**

<https://arxiv.org/abs/2101.03961>



# Outline



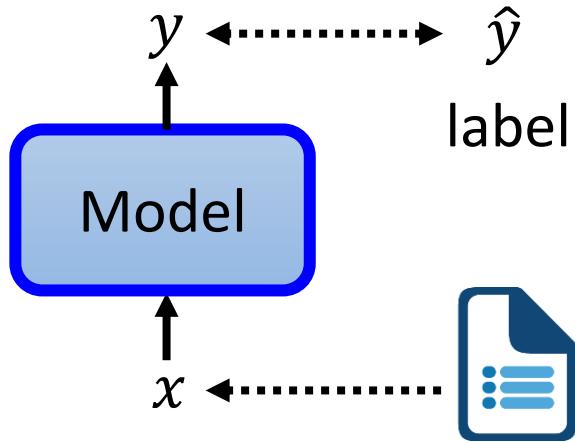
BERT series



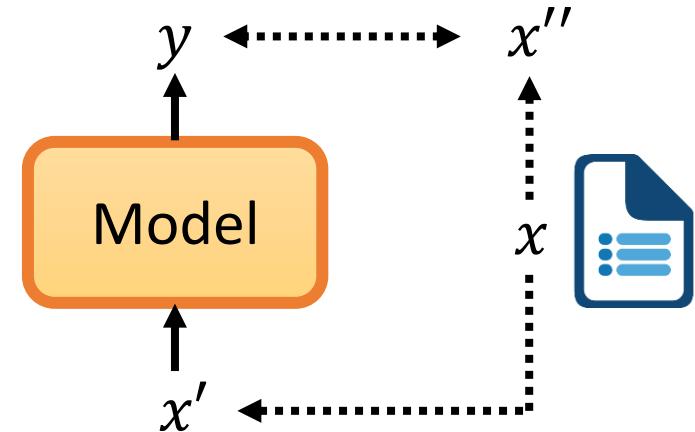
GPT series

# Self-supervised Learning

Supervised



Self-supervised



Yann LeCun

2019年4月30日 · ●

...

I now call it "self-supervised learning", because "unsupervised" is both a loaded and confusing term.

In self-supervised learning, the system learns to predict part of its input from other parts of its input. In other words a portion of the input is used as a supervisory signal to a predictor fed with the remaining portion of the input.

# Masking Input

<https://arxiv.org/abs/1810.04805>



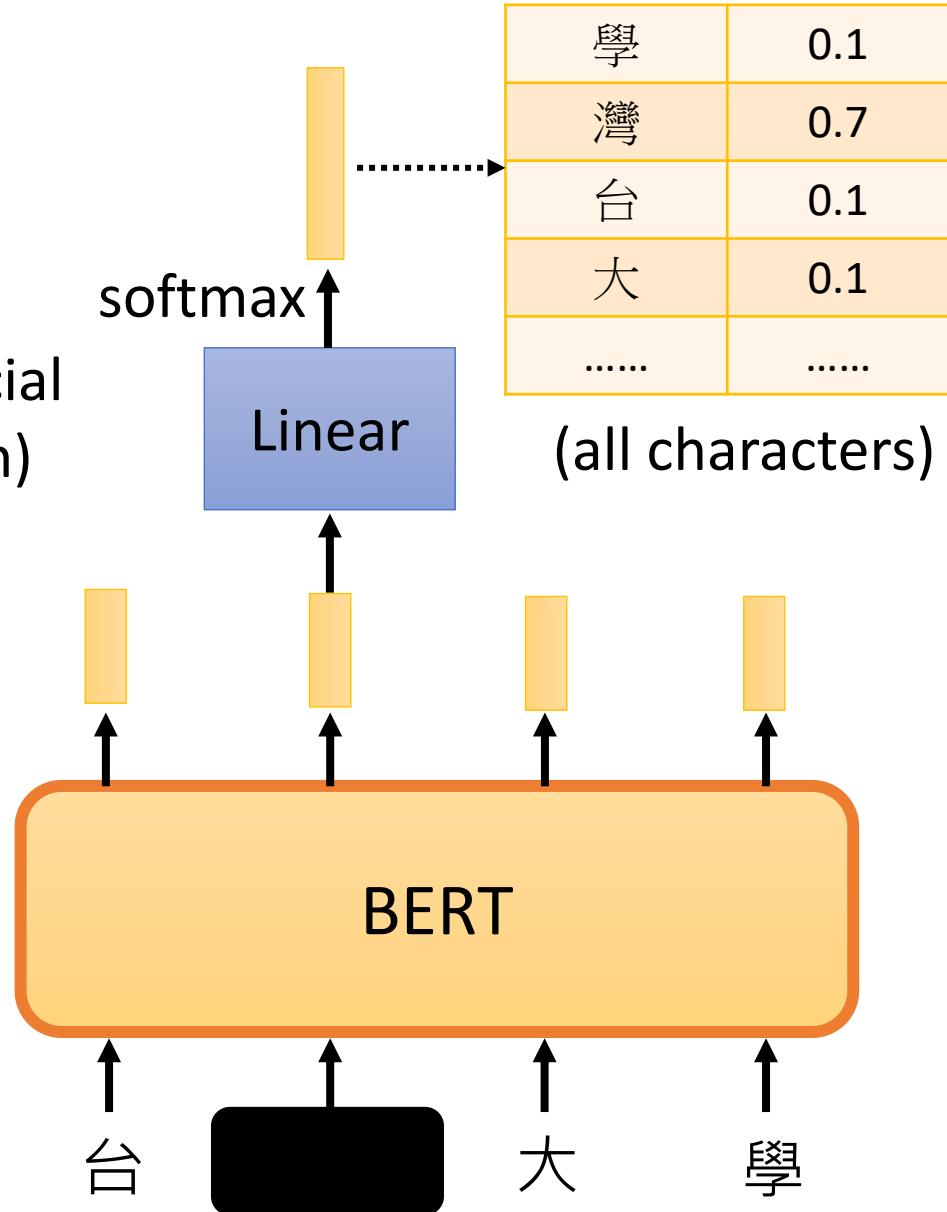
= MASK (special token)  
or



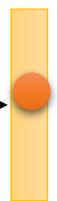
= Random  
一、天、大、小 ...

Transformer Encoder

Randomly masking some tokens



Ground  
truth



灣

# Masking Input

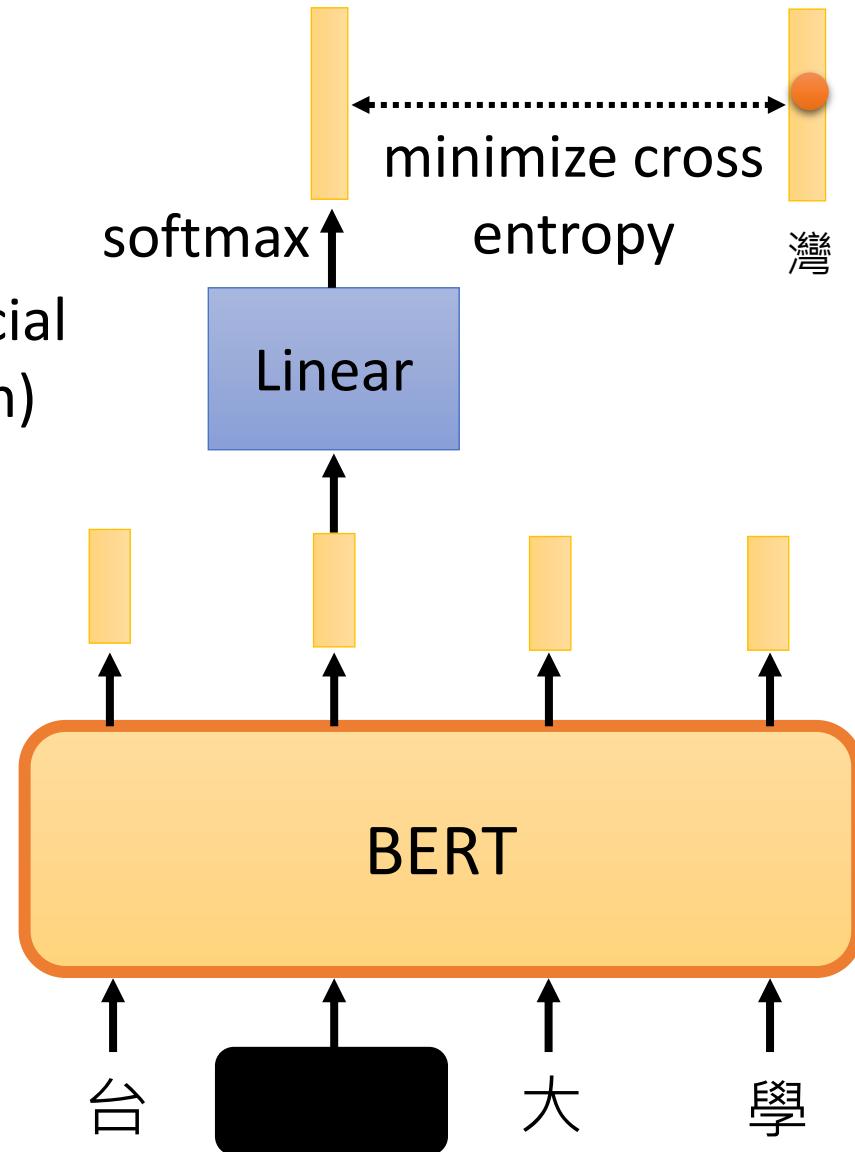
<https://arxiv.org/abs/1810.04805>

= MASK (special token)  
or

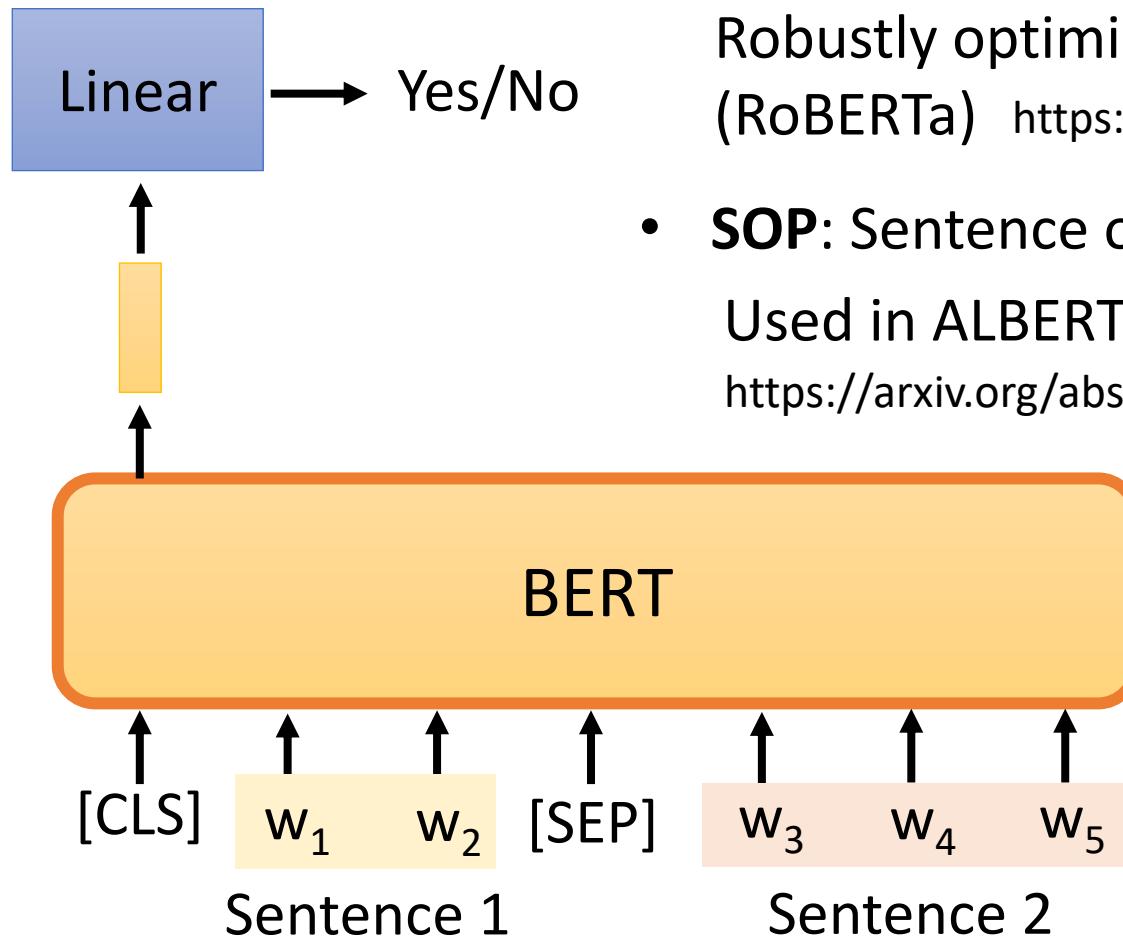
= Random  
一、天、大、小 ...

Transformer  
Encoder

Randomly masking  
some tokens

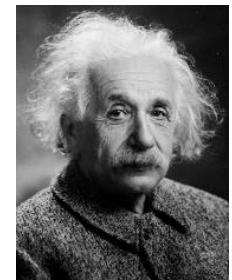


# Next Sentence Prediction



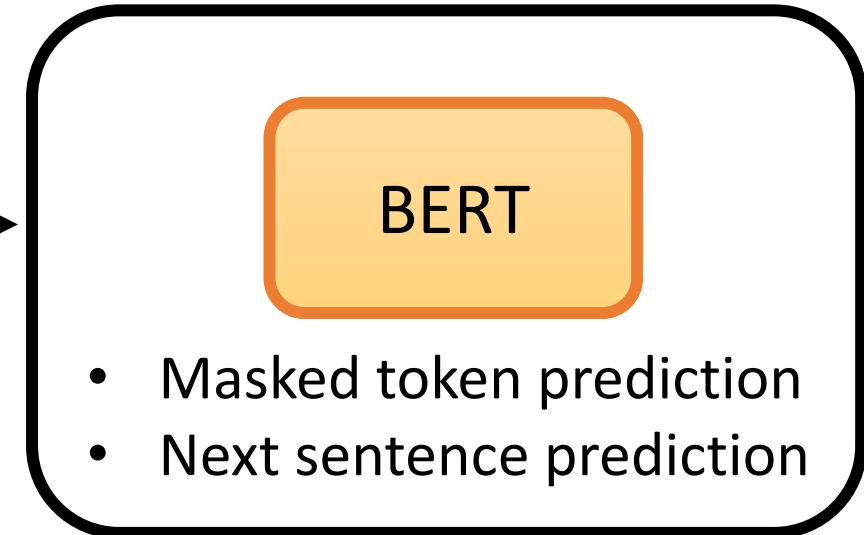
- This approach is not helpful.
- Robustly optimized BERT approach  
(RoBERTa) <https://arxiv.org/abs/1907.11692>

- **SOP:** Sentence order prediction  
Used in ALBERT  
<https://arxiv.org/abs/1909.11942>





Self-supervised  
Learning  
**Pre-train**



**Fine-tune**

Model for  
Task 1

Model for  
Task 2

Model for  
Task 3

## Downstream Tasks

- The tasks we care
- We have a little bit labeled data.

# GLUE

## General Language Understanding Evaluation (GLUE)

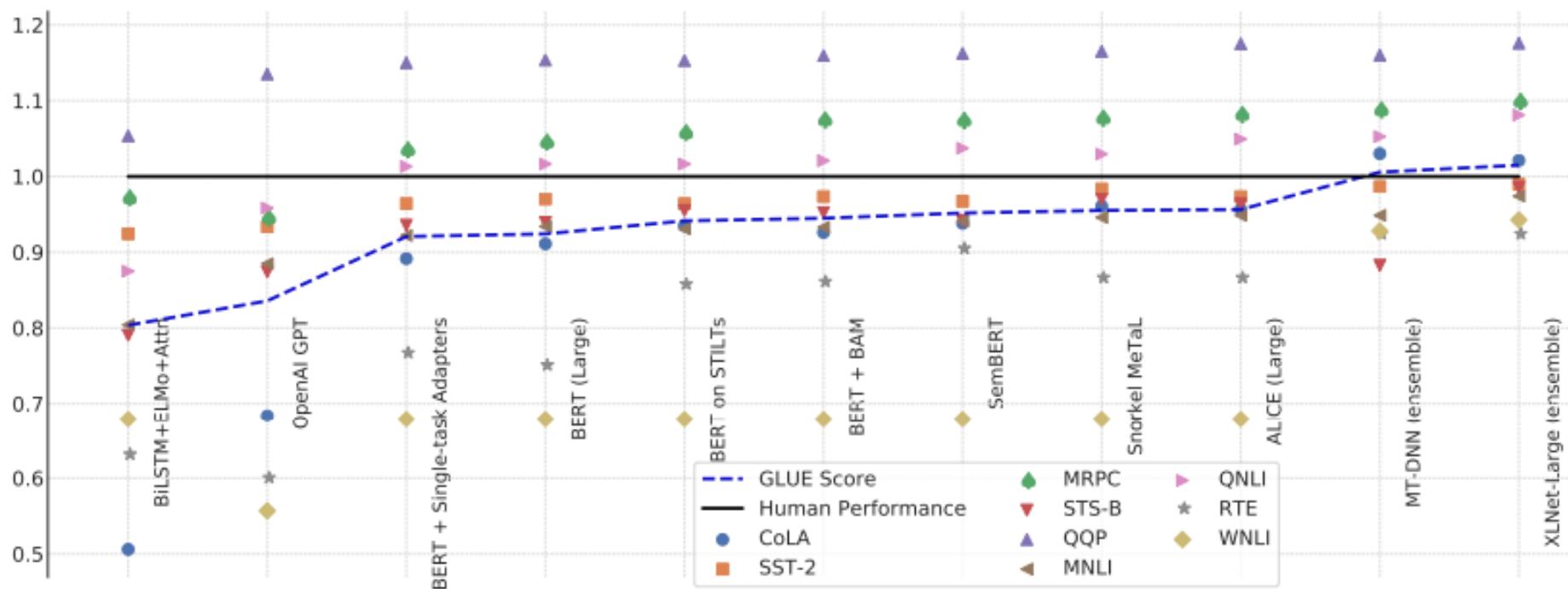
<https://gluebenchmark.com/>

- Corpus of Linguistic Acceptability (CoLA)
- Stanford Sentiment Treebank (SST-2)
- Microsoft Research Paraphrase Corpus (MRPC)
- Quora Question Pairs (QQP)
- Semantic Textual Similarity Benchmark (STS-B)
- Multi-Genre Natural Language Inference (MNLI)
- Question-answering NLI (QNLI)
- Recognizing Textual Entailment (RTE)
- Winograd NLI (WNLI)

GLUE also has Chinese version (<https://www.cluebenchmarks.com/>)

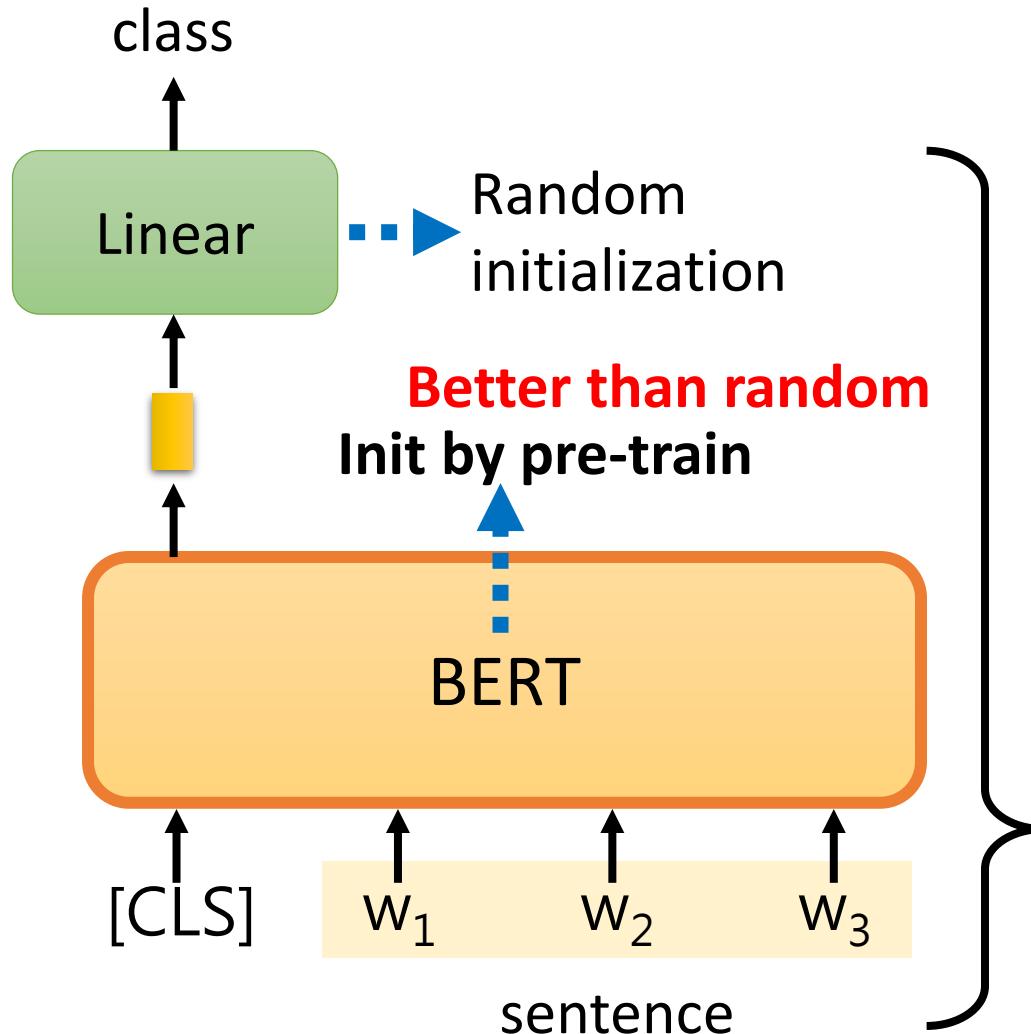
# BERT and its Family

- GLUE scores



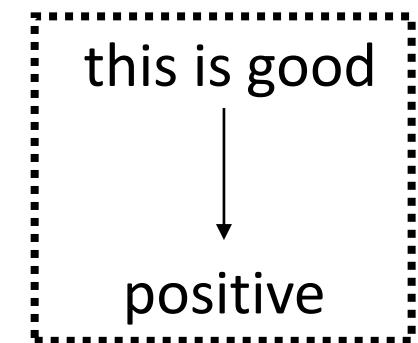
Source of image: <https://arxiv.org/abs/1905.00537>

# How to use BERT – Case 1



Input: sequence  
output: class

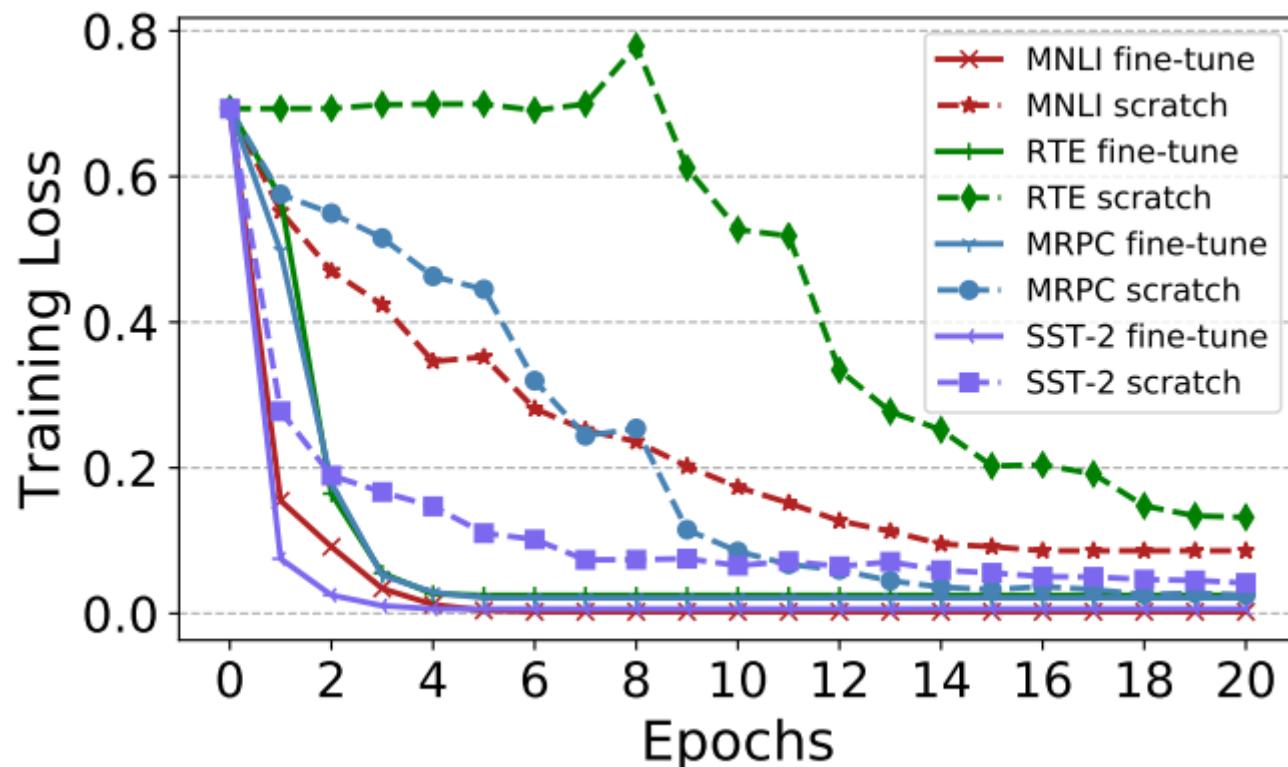
Example:  
Sentiment analysis



This is the model  
to be learned.

# Pre-train v.s. Random Initialization

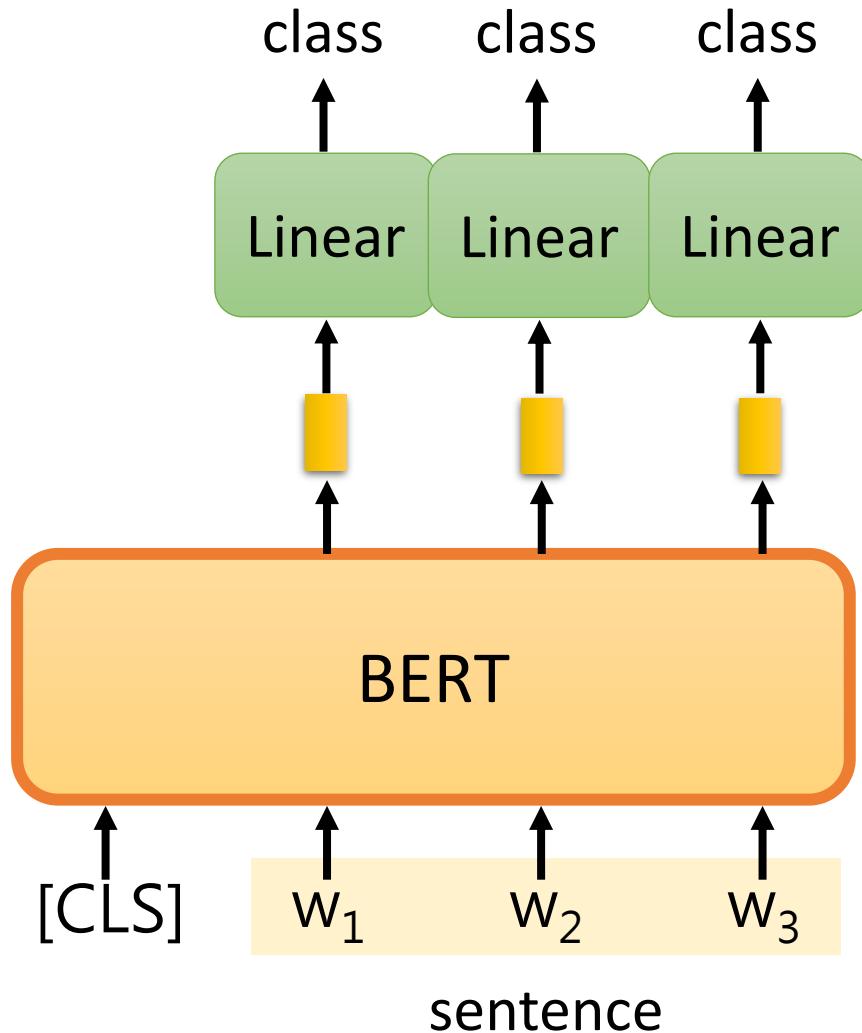
(fine-tune) (scratch)



Source of image: <https://arxiv.org/abs/1908.05620>

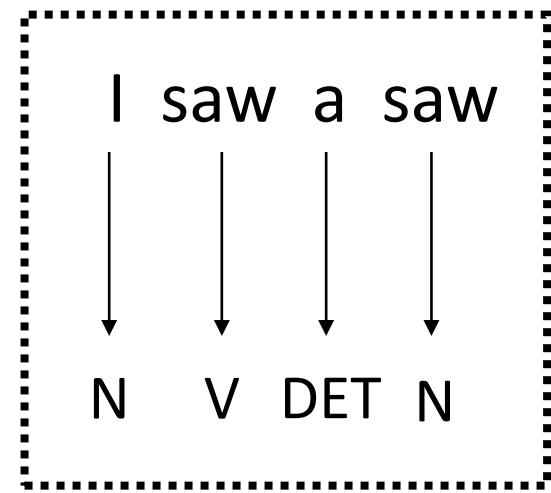
# Q&A

# How to use BERT – Case 2



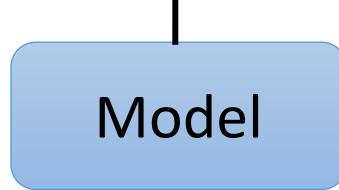
Input: sequence  
output: same as input

Example:  
POS tagging



# How to use BERT – Case 3

contradiction  
entailment  
neutral



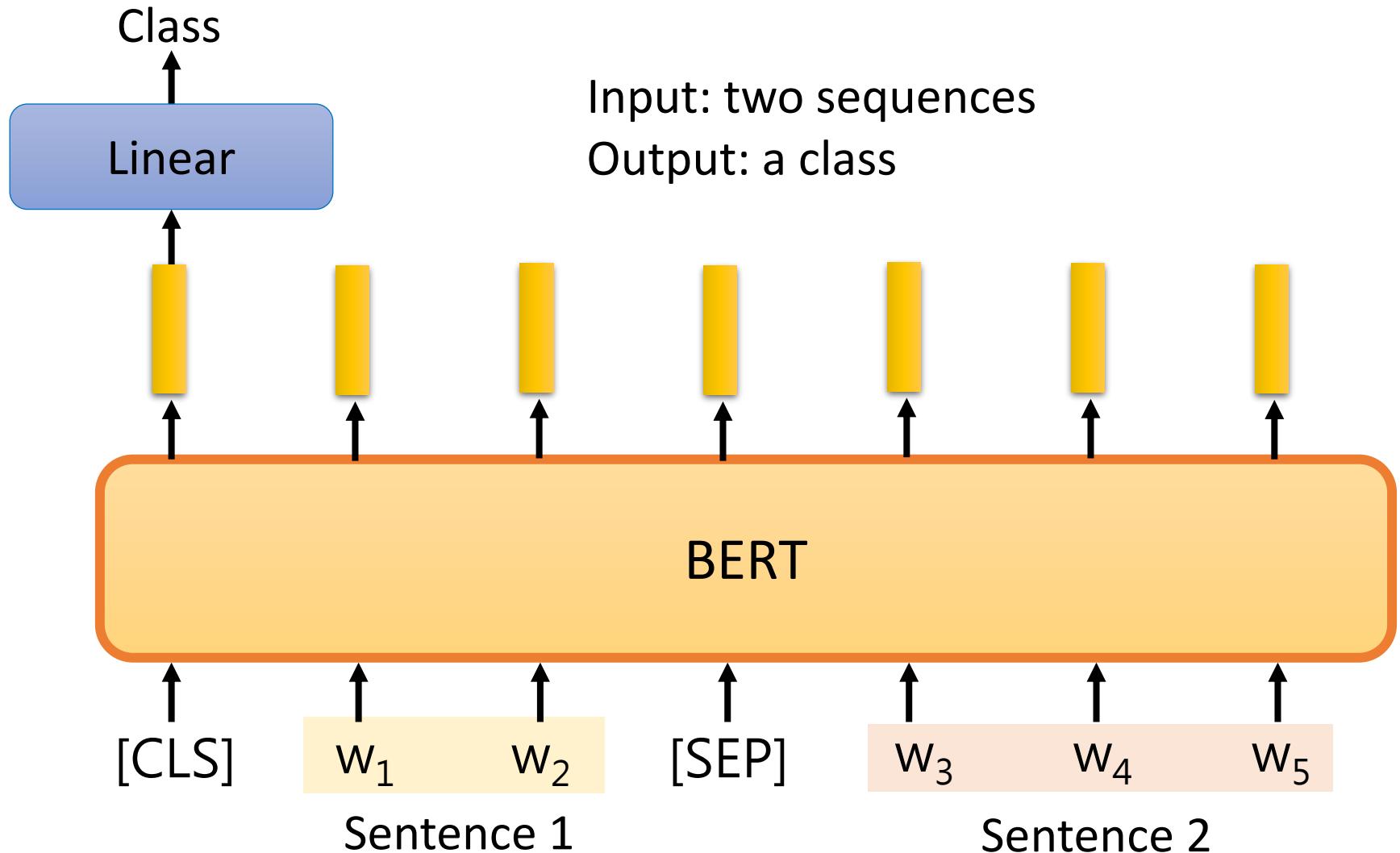
Input: two sequences  
Output: a class

Example:  
Natural Language Inferencee (NLI)

hypothesis: A person is at a diner. contradiction

premise: A person on a horse jumps over a broken down airplane

# How to use BERT – Case 3

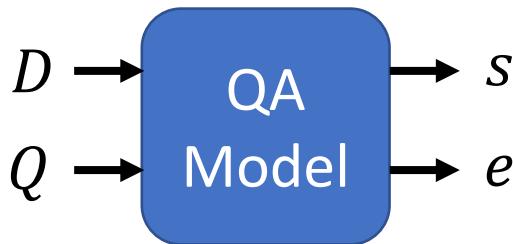


# How to use BERT – Case 4

- Extraction-based Question Answering (QA)

**Document:**  $D = \{d_1, d_2, \dots, d_N\}$

**Query:**  $Q = \{q_1, q_2, \dots, q_M\}$



output: two integers ( $s, e$ )

**Answer:**  $A = \{d_s, \dots, d_e\}$

In meteorology, precipitation is any product of the condensation of atmospheric water vapor that falls under **gravity**. The main forms of precipitation include drizzle, rain, sleet, snow, **graupel** and hail... Precipitation forms as smaller droplets coalesce via collision with other rain drops or ice crystals **within a cloud**. Short, intense periods of rain 77 atte 79 cations are called "showers".

What causes precipitation to fall?

**gravity**  $s = 17, e = 17$

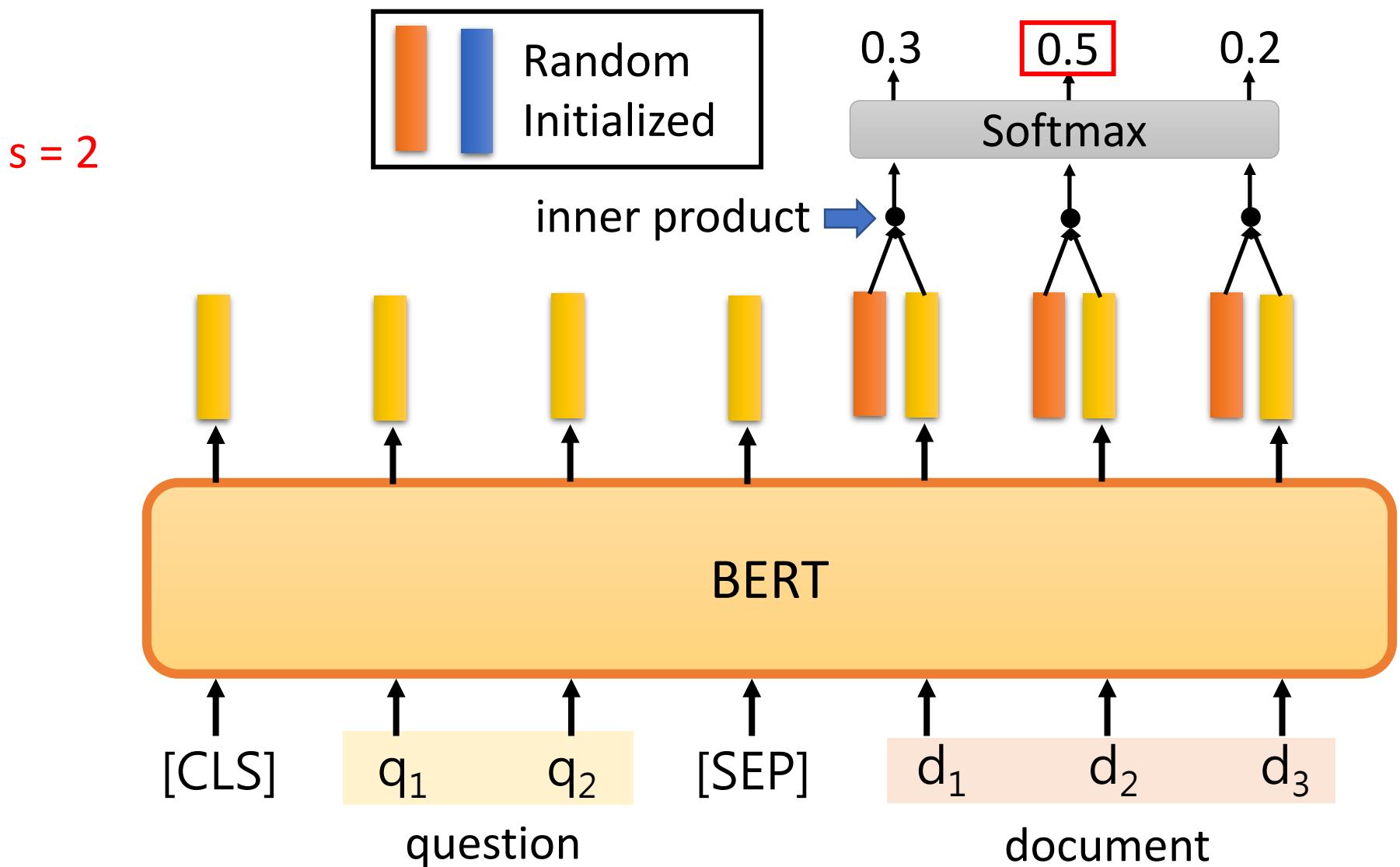
What is another main form of precipitation besides drizzle, rain, snow, sleet and hail?

**graupel**

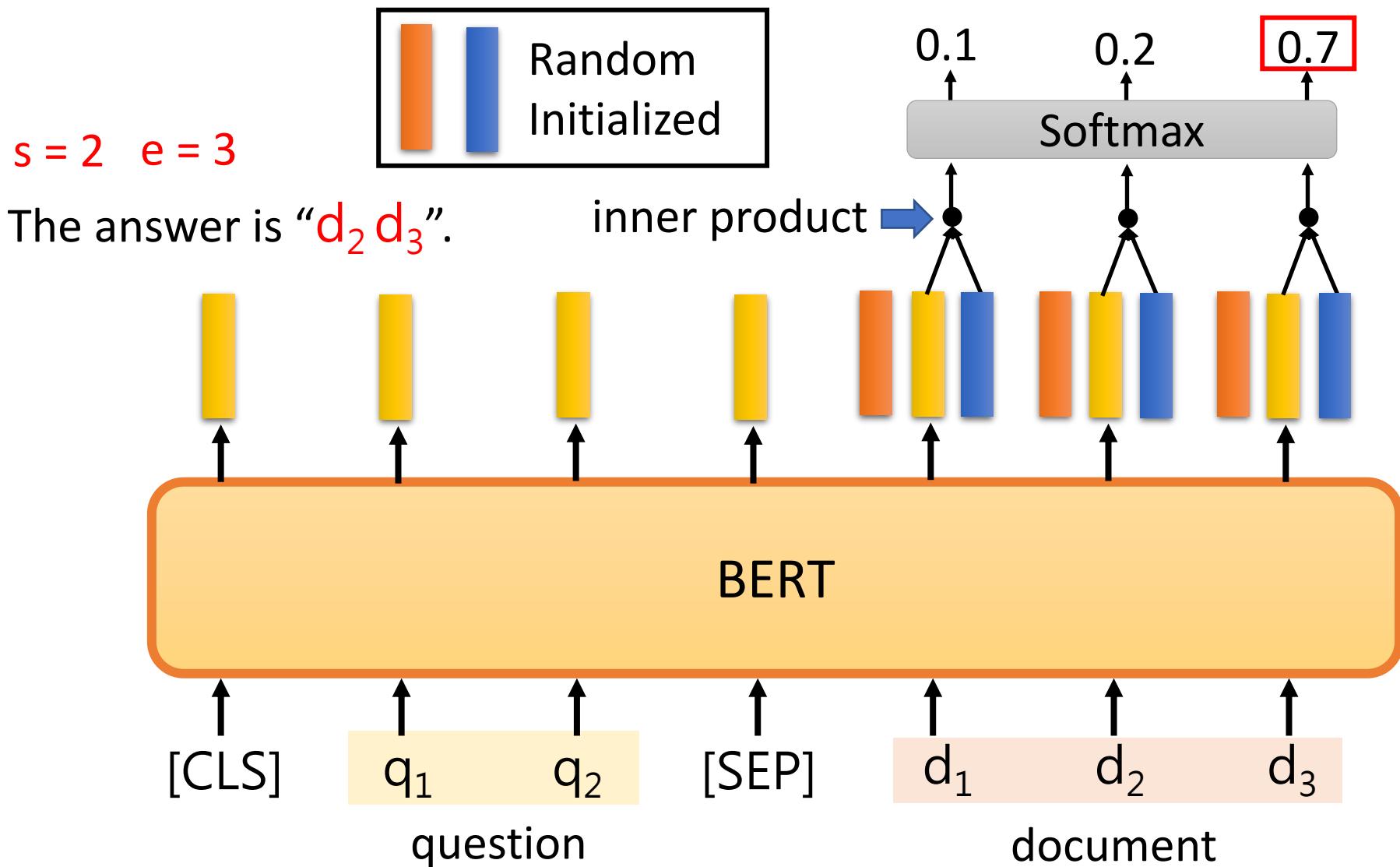
Where do water droplets collide with ice crystals to form precipitation?

**within a cloud**  $s = 77, e = 79$

# How to use BERT – Case 4



# How to use BERT – Case 4



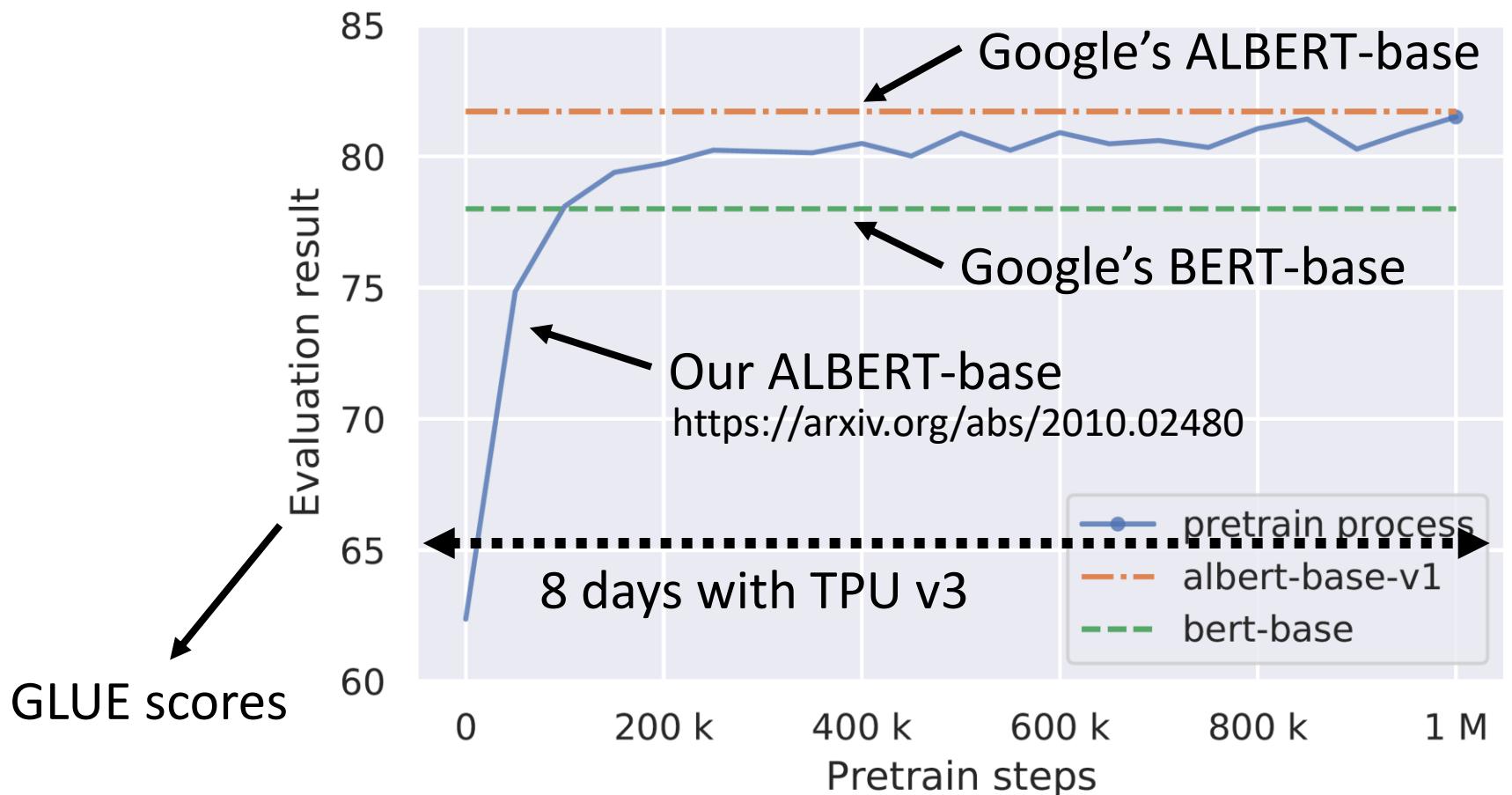
That's  
all!



# Training BERT is challenging!

Training data has more than **3 billions** of words.

**3000 times of Harry Potter series**



# BERT Embryology (胚胎學)

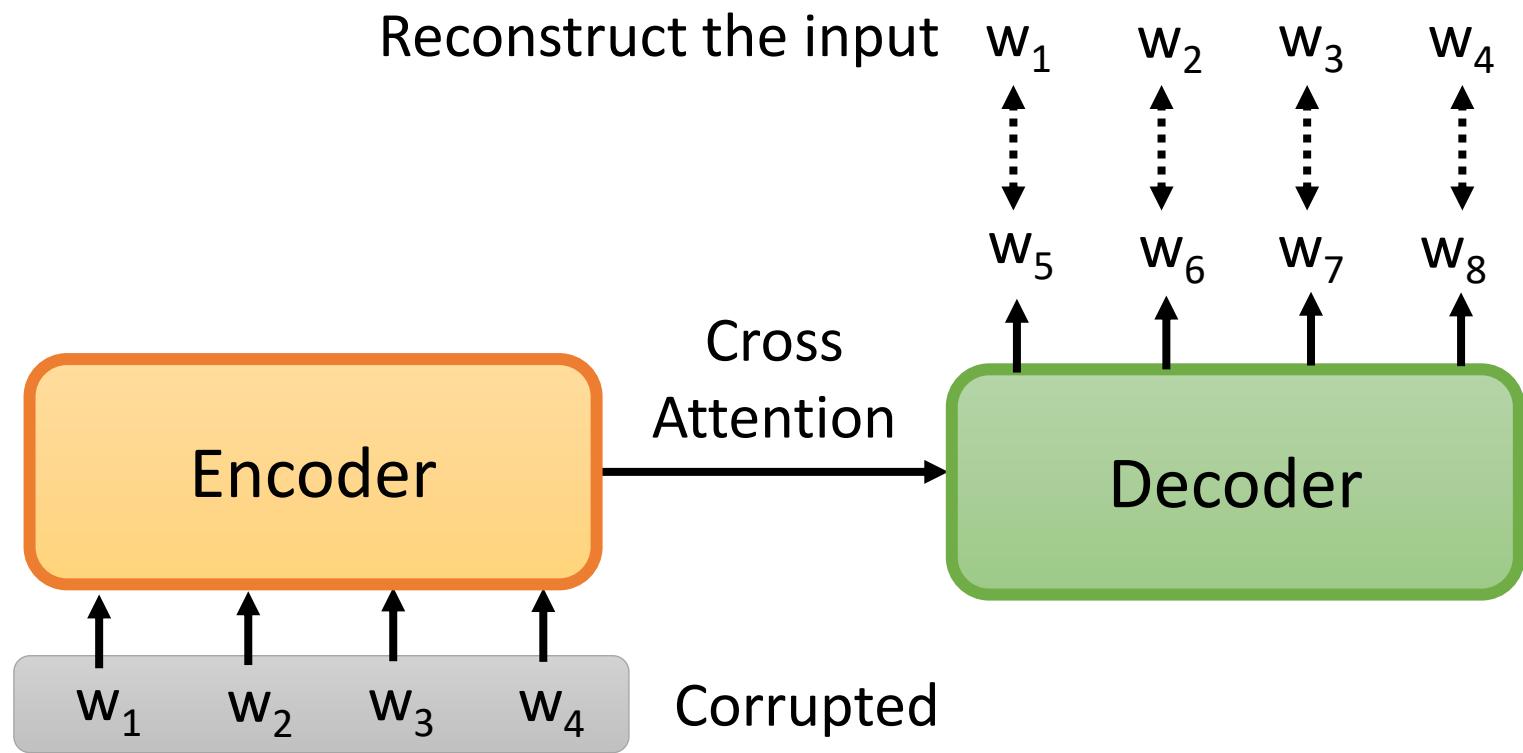
<https://arxiv.org/abs/2010.02480>



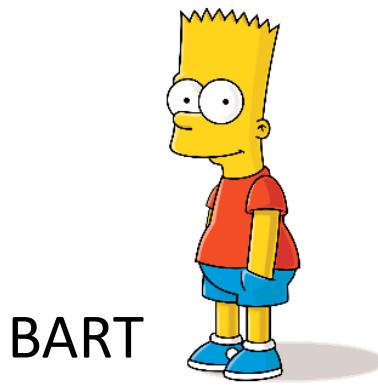
When does BERT know POS tagging,  
syntactic parsing, semantics?

The answer is counterintuitive!

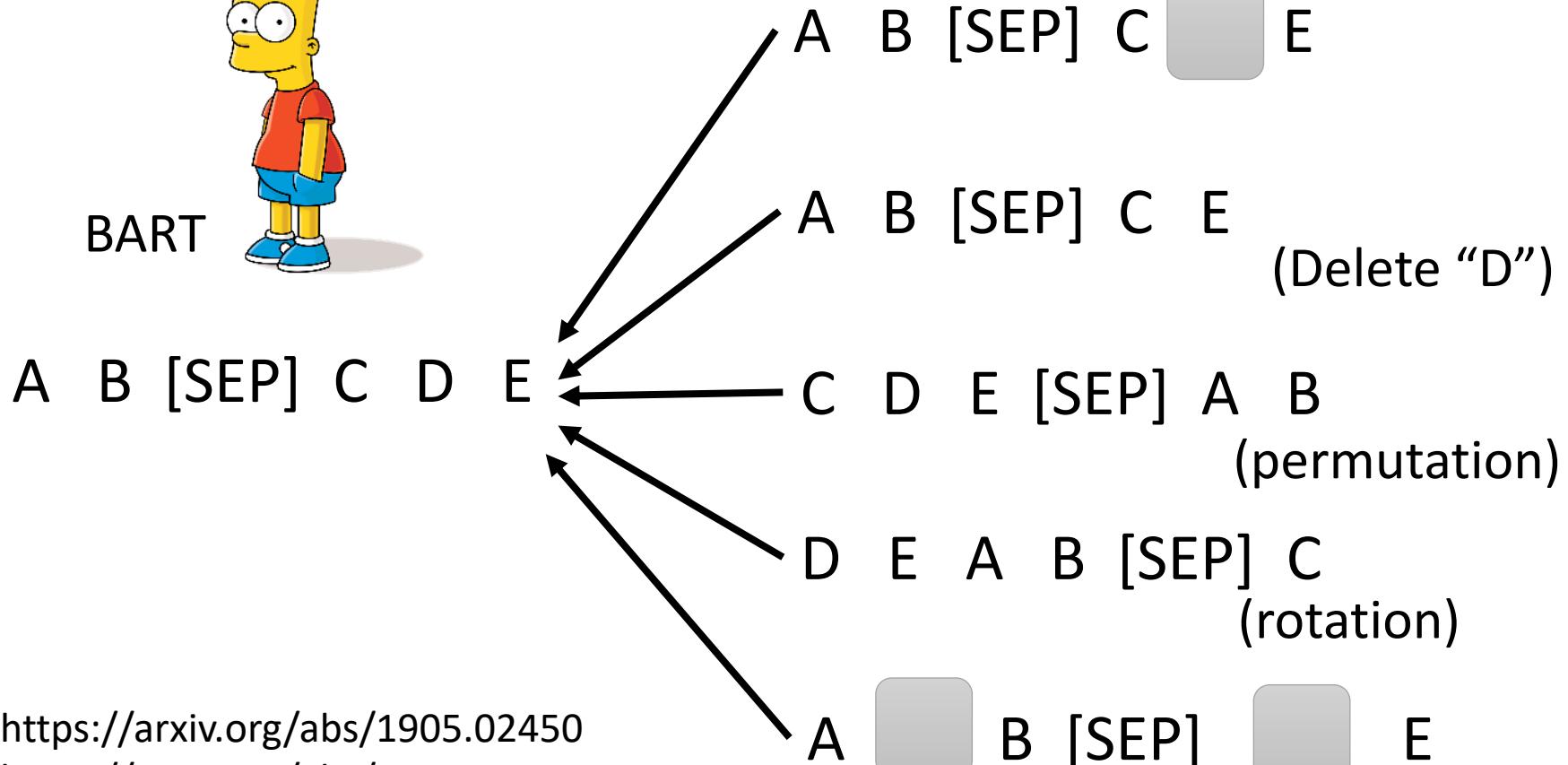
# Pre-training a seq2seq model



# MASS / BART



MASS



**Text Infilling**



# T5 – Comparison

- Transfer Text-to-Text Transformer (T5)
- Colossal Clean Crawled Corpus (C4)

Objective	Inputs	Targets
Prefix language modeling	Thank you for inviting	me to your party last week .
BERT-style	Thank you <M> <M> me to your party apple week .	(original text)
Deshuffling	party me for your to . las	
I.i.d. noise, mask tokens	Thank you <M> <M> me to	
I.i.d. noise, replace spans	Thank you <X> me to you	
I.i.d. noise, drop tokens	Thank you me to your pa	
Random spans	Thank you <X> to <Y> we	

High-level approaches

Language modeling

BERT-style

Deshuffling

Corruption strategies

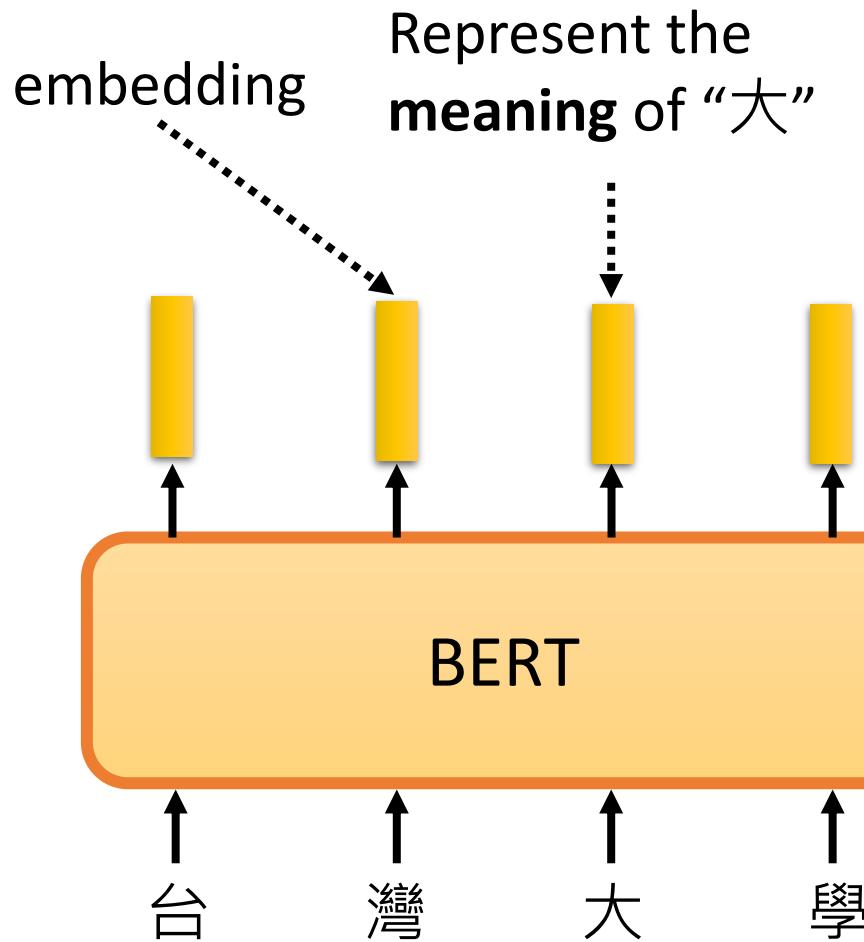
Mask

Replace spans

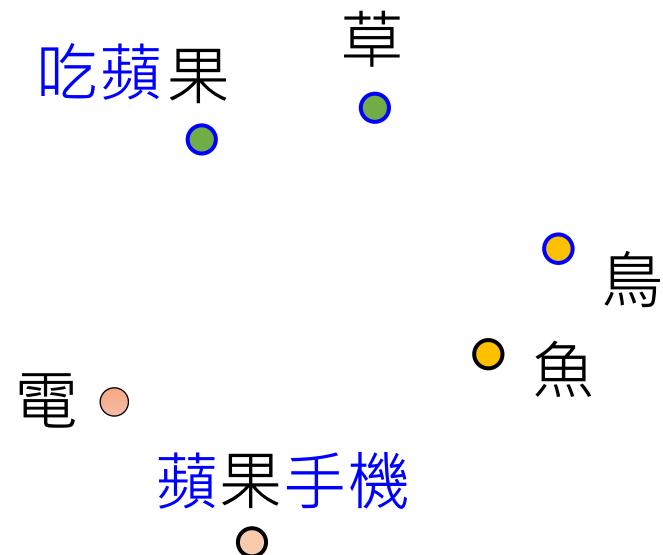
Drop

Corruption rate	Corrupted span length
10%	2
15%	3
25%	5
50%	10

# Why does BERT work?

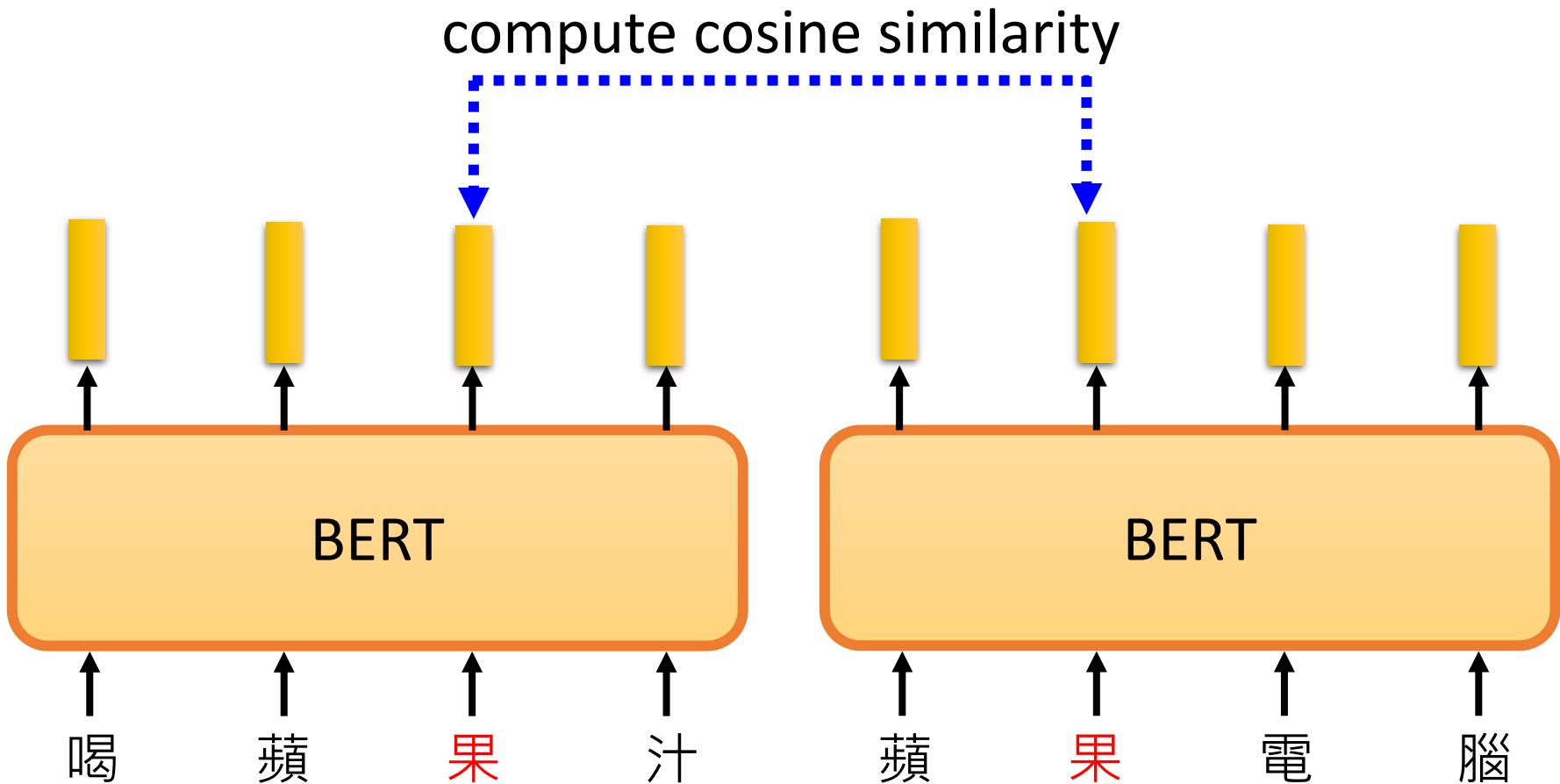


The tokens with similar meaning have similar embedding.

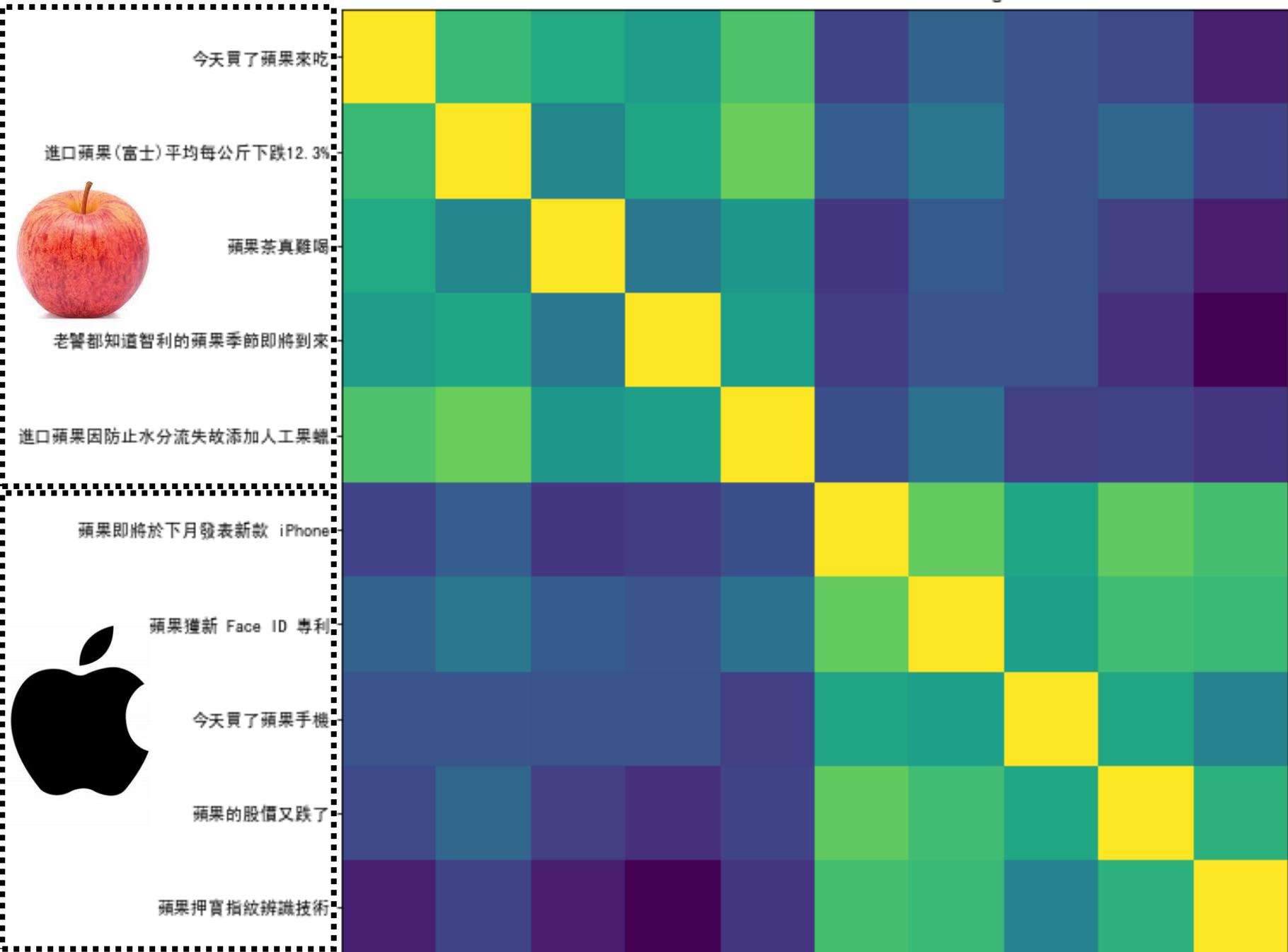


**Context is considered.**

# Why does BERT work?



Cosine Similarities of BERT Embeddings



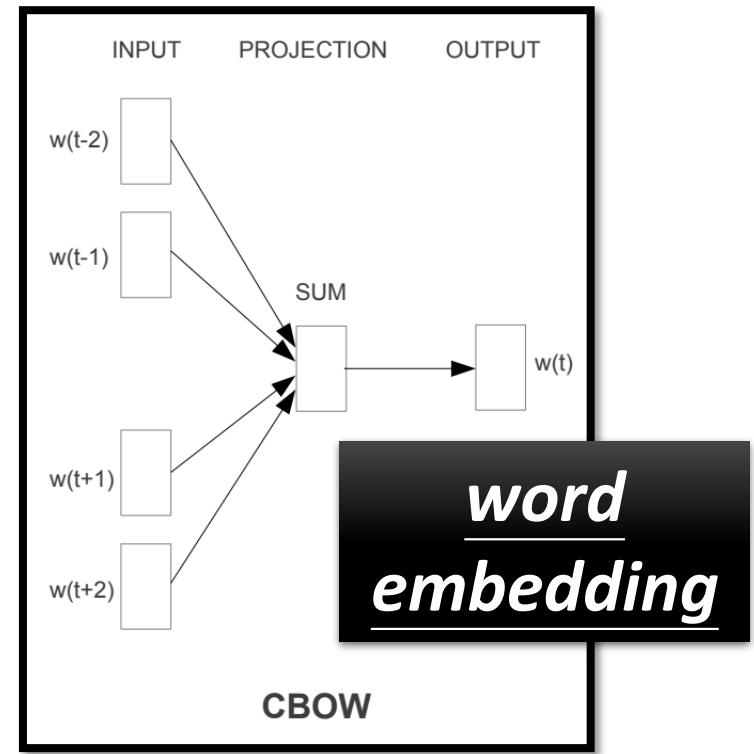
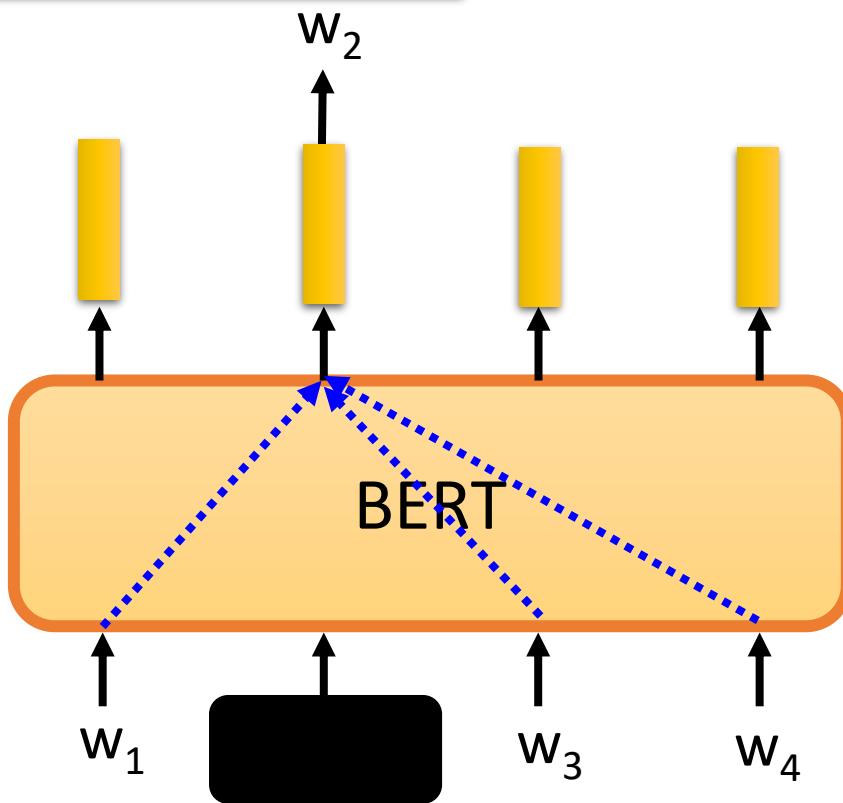
# Why does BERT work?

**Contextualized  
word embedding**

You shall know a word by  
the company it keeps

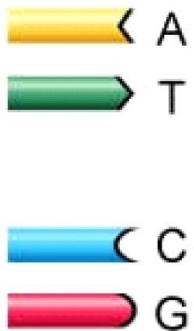
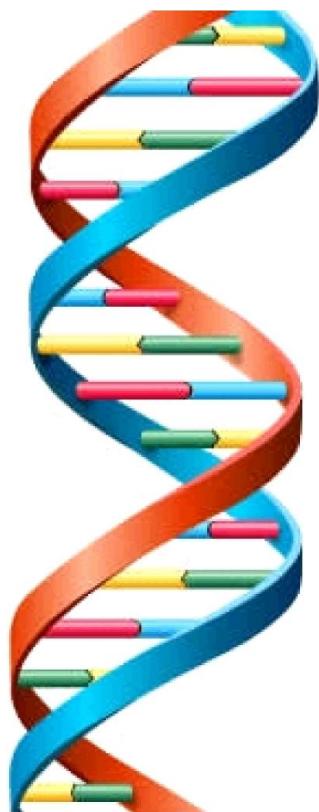


John Rupert Firth



# Why does BERT work?

- Applying BERT to **protein, DNA, music classification**

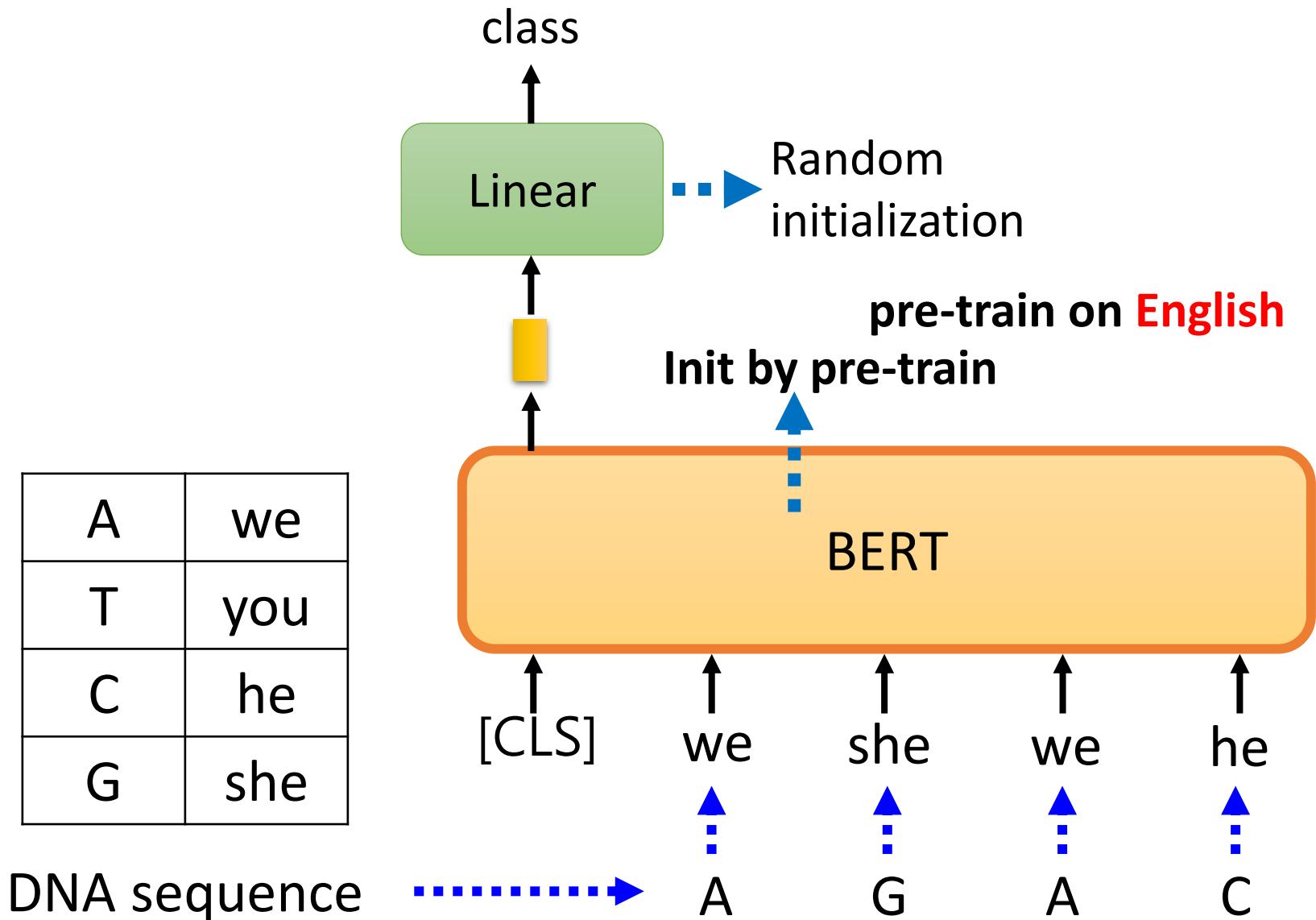


class	DNA sequence
EI	CCAGCTGCATCACAGGAGGCCAGCG
EI	AGACCCGCCGGAGGGCGGAGGGACCG
IE	AACGTGGCCTCCTTGTGCCCTTCCCC
IE	CCACTCAGCCAGGCCCTTCTTCTCCT
IE	CCTGATCTGGGTCTCCCCTCCCACCC
IE	AGCCCTCAACCCTTCTGTCTCACCC
IE	CCACTCAGCCAGGCCCTTCTTCTCCT
N	CTGTGTTACCAACATCAAGCGCCGGG
N	GTGTTACCGAGGGCATTCTAACAGT
N	TCTGAGCTCTGCATTGTCTATTCTCC

# Why does BERT work?

<https://arxiv.org/abs/2103.07162>

This work is done by 高瑋聰



# Why does BERT work?

- Applying BERT to **protein, DNA, music classification**

	Protein			DNA				Music
	localization	stability	fluorescence	H3	H4	H3K9ac	Splice	composer
specific	69.0	76.0	63.0	87.3	87.3	79.1	94.1	-
BERT	64.8	74.5	63.7	83.0	86.2	78.3	97.5	55.2
re-emb	63.3	75.4	37.3	78.5	83.7	76.3	95.6	55.2
rand	58.6	65.8	27.5	75.6	66.5	72.8	95	36



# To Learn More .....

**BERT (Part 1)**



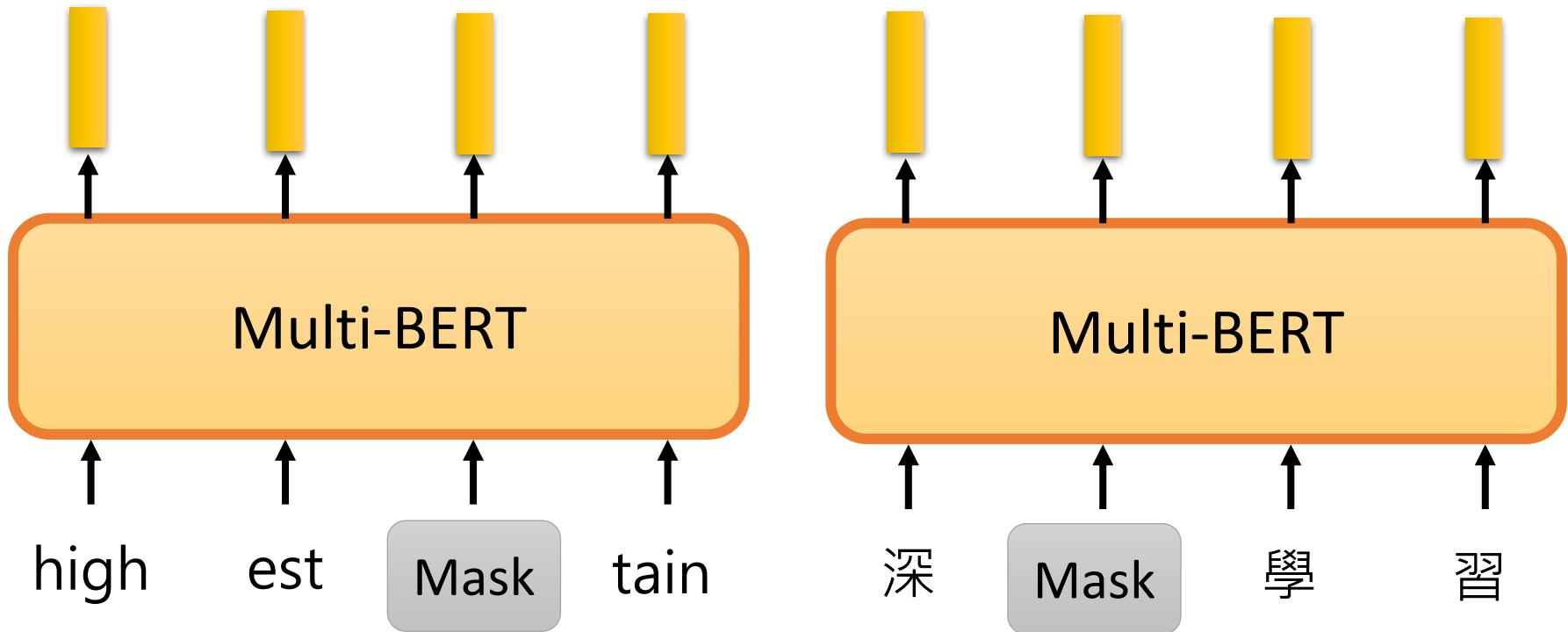
[https://youtu.be/1\\_gRK9EIQpc](https://youtu.be/1_gRK9EIQpc)

**BERT (Part 2)**



<https://youtu.be/Bywo7m6ySlk>

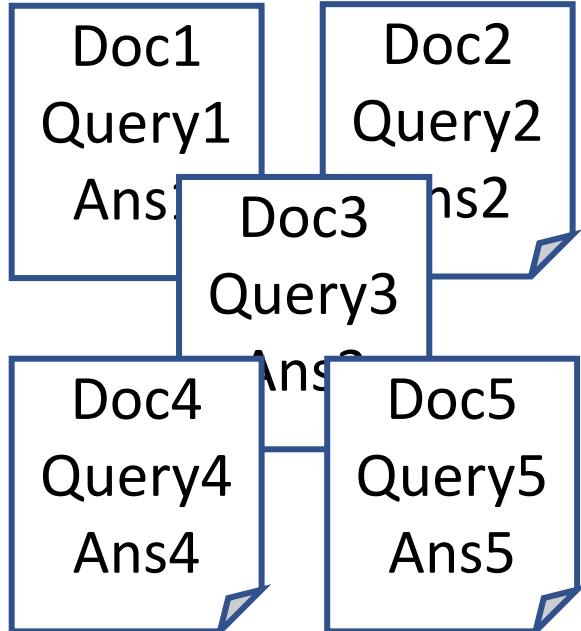
# Multi-lingual BERT



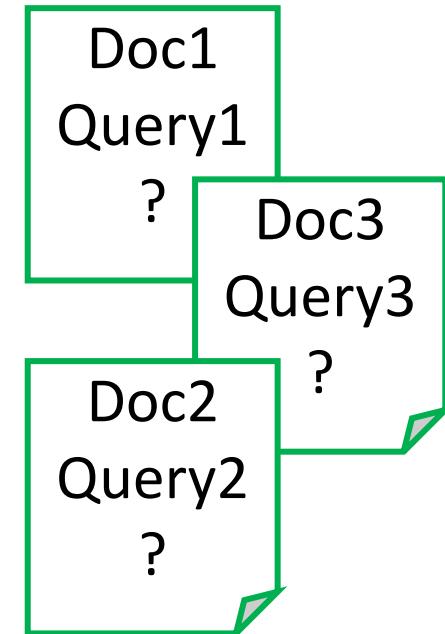
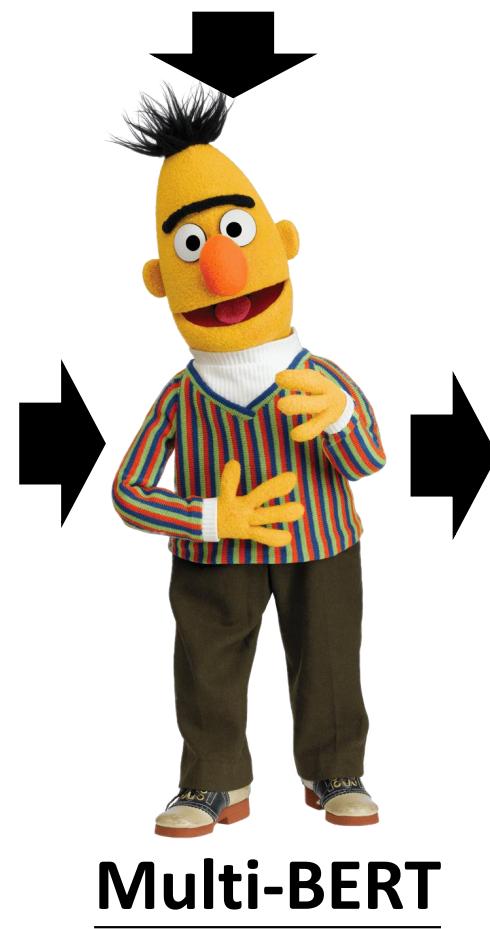
Training a BERT model by many different languages.

# Zero-shot Reading Comprehension

Training on the sentences of 104 languages



Train on **English** QA  
training examples



Test on **Chinese**  
QA test

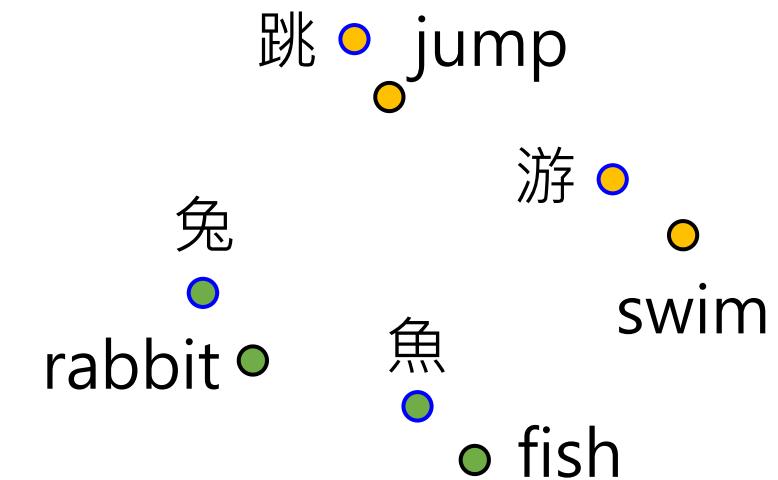
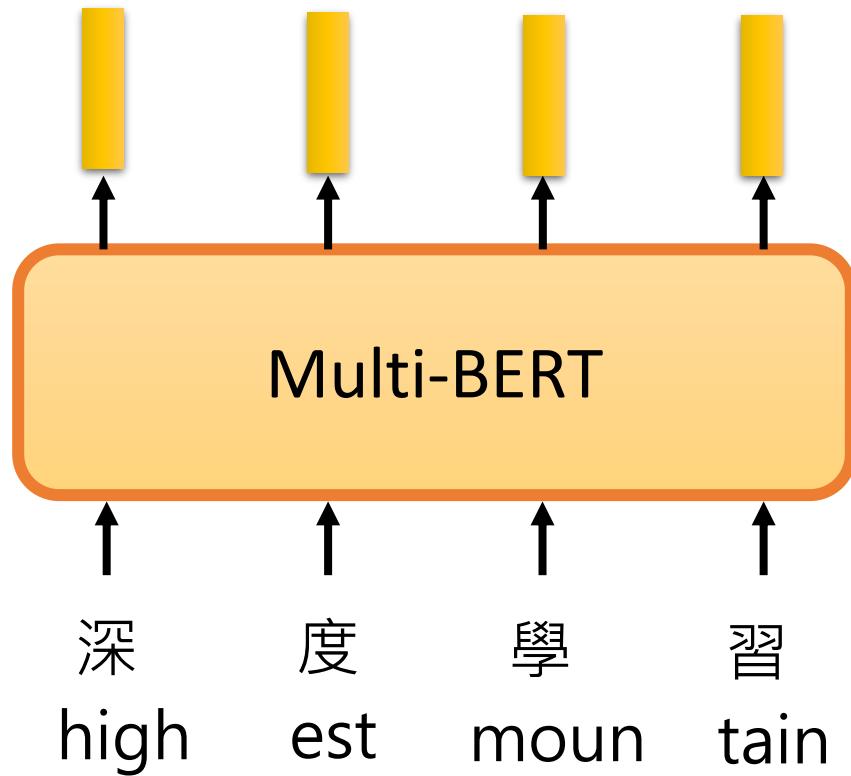
# Zero-shot Reading Comprehension

- English: SQuAD, Chinese: DRCD

Model	Pre-train	Fine-tune	Test	EM	F1
QANet	none	Chinese		66.1	78.1
BERT	Chinese	Chinese	Chinese	82.0	89.1
	104 languages	Chinese		81.2	88.7
		English		63.3	78.8
		Chinese + English		82.6	90.1

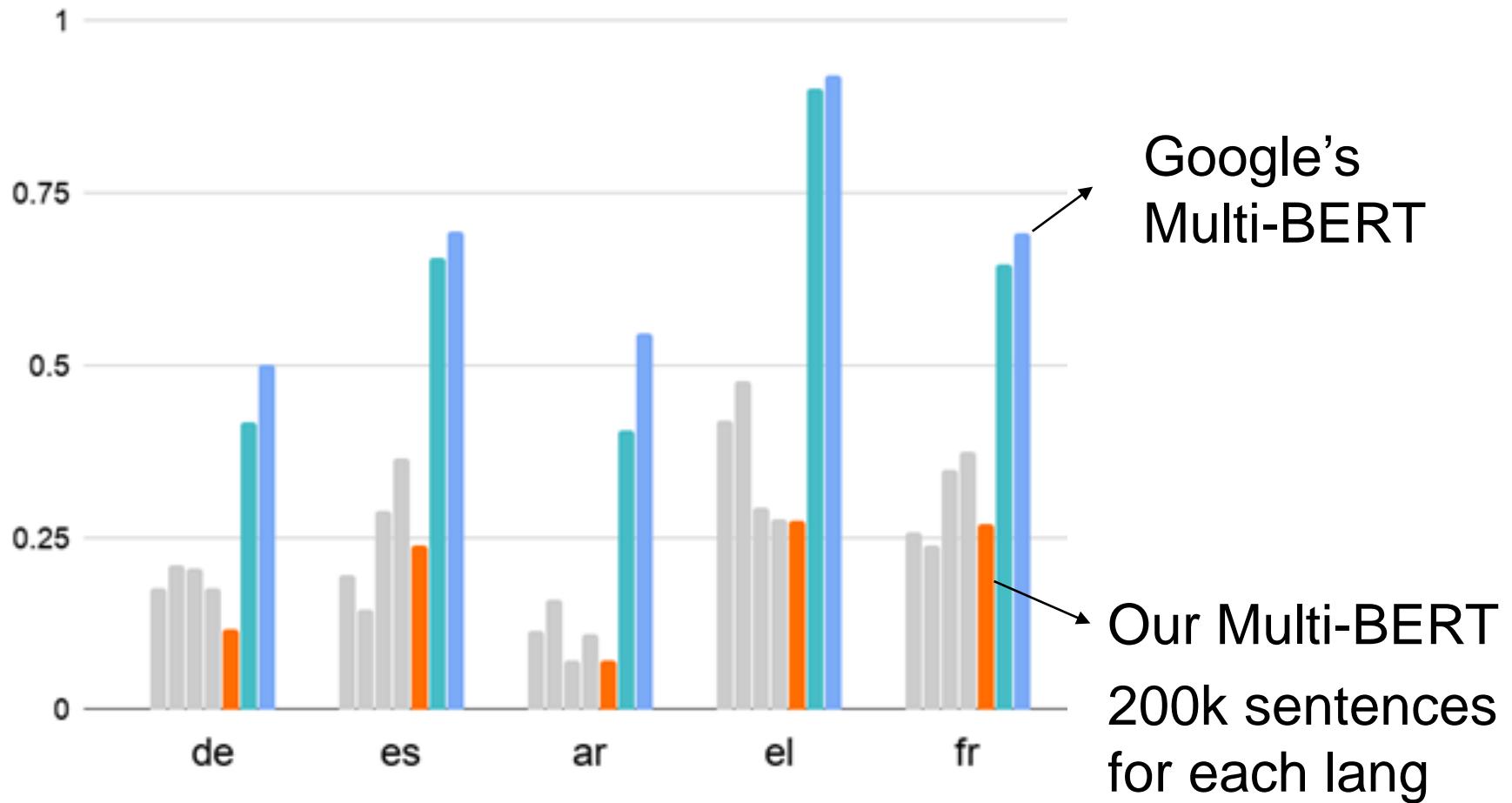
F1 score of Human performance is 93.30%

# Cross-lingual Alignment?



# Mean Reciprocal Rank (MRR):

## Higher MRR, better alignment



<https://arxiv.org/abs/2010.10938>

投影片來源: 許宗嫄同學碩士口試投影片

How about 1000k?

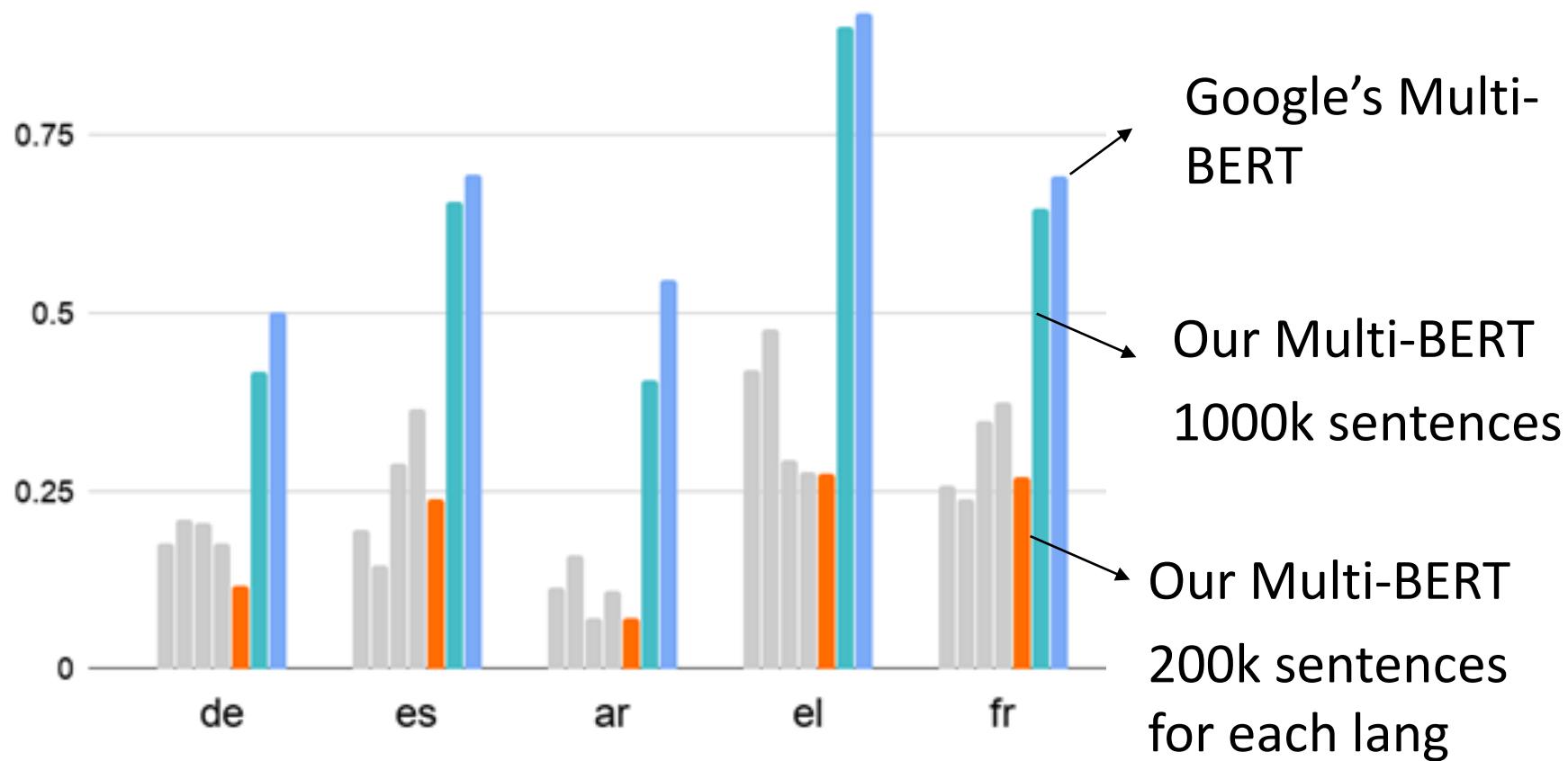
# The training is also challenging ...



## Mean Reciprocal Rank (MRR):

Higher MRR, better alignment

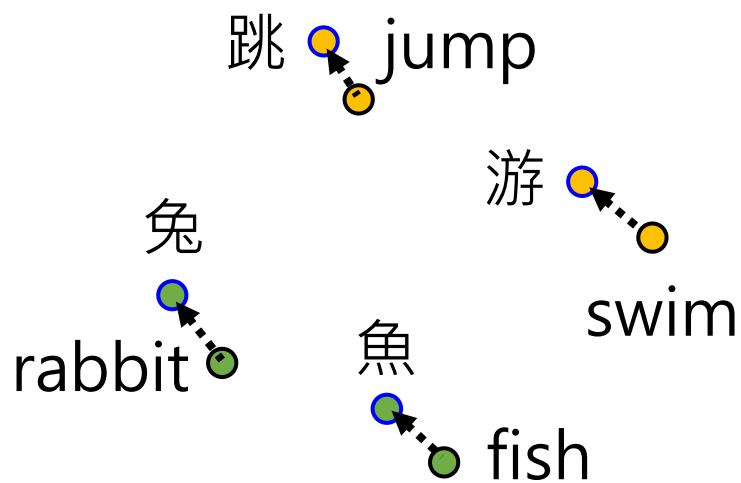
1 The amount of training data is critical for alignment.



<https://arxiv.org/abs/2010.10938>

投影片來源: 許宗嫄同學碩士口試投影片

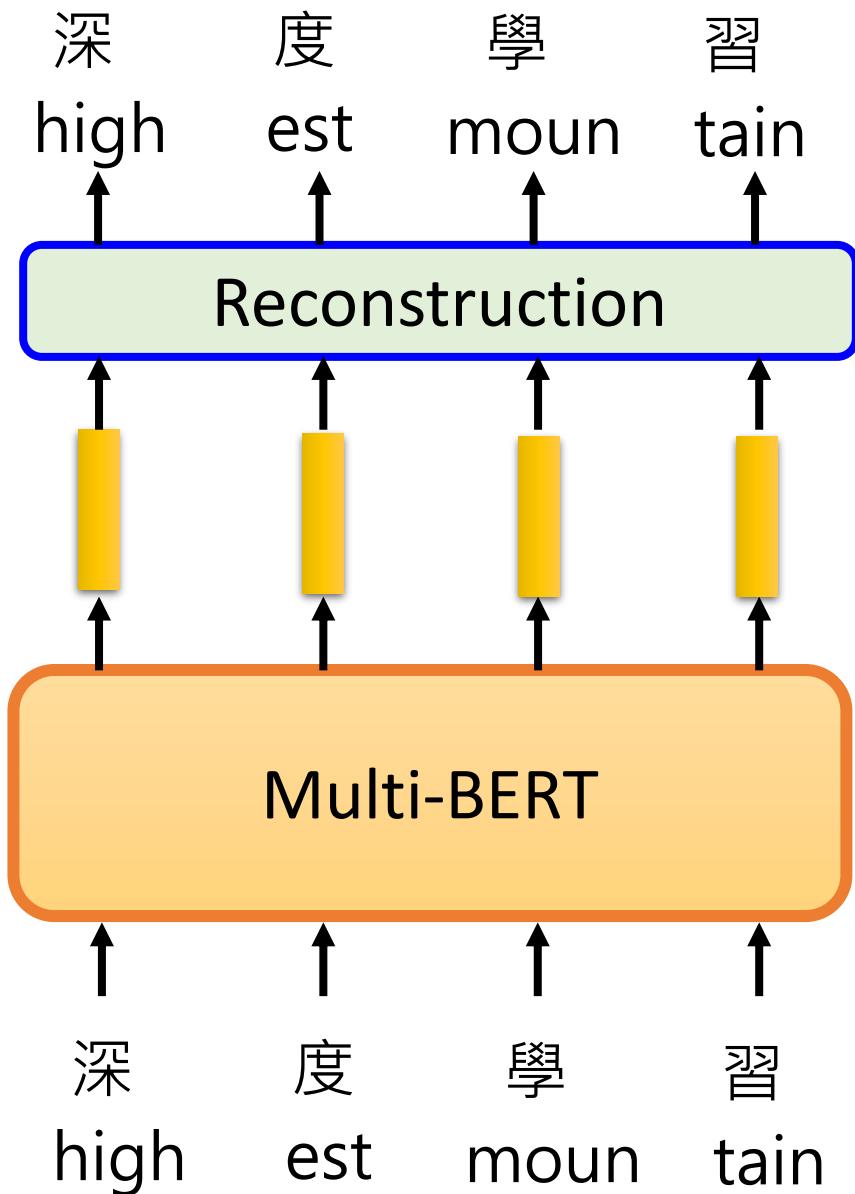
# Weird???



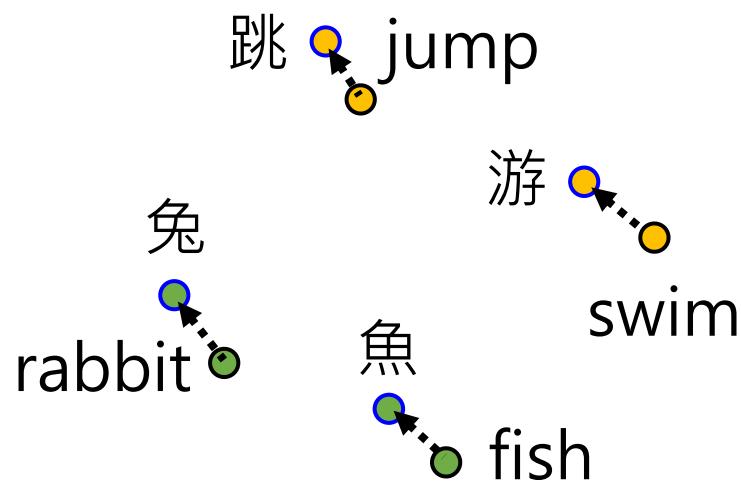
If the embedding is language independent ...

How to correctly reconstruct?

There must be language information.



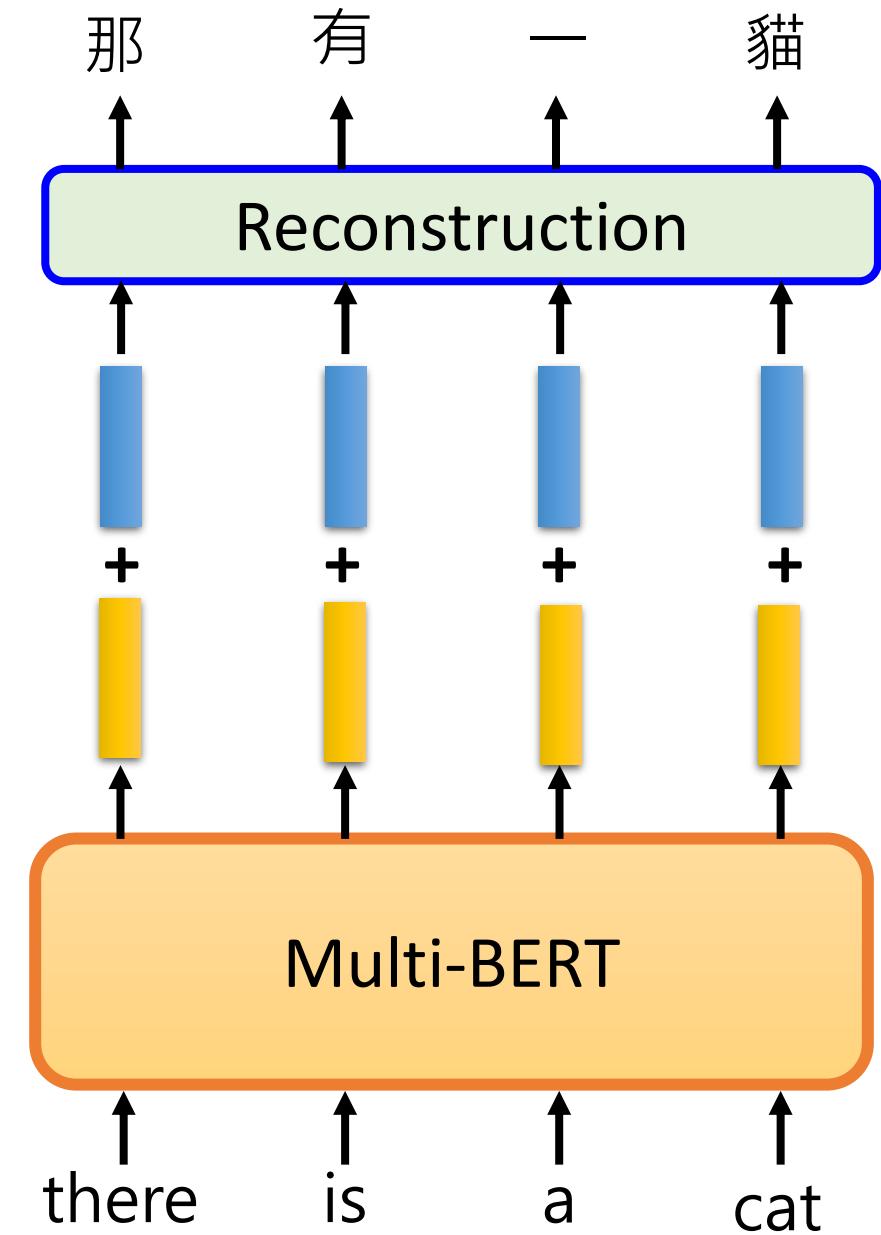
# Where is Language?



Average of  
Chinese

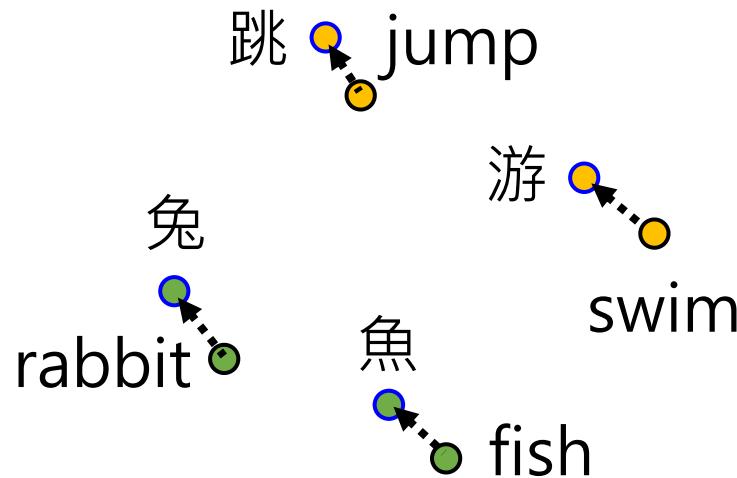


Average of  
English



# If this is true ...

This work is done by 劉記良、許宗嫄、莊永松  
<https://arxiv.org/abs/2010.10041>



Average of  
Chinese



Average of  
English

---

Input (en) | The girl that can help me is all the way across town. There is no one who can help me.

Ground Truth (zh) | 能帮助我的女孩在小镇的另一边。没有人能帮助我。。

en→zh,  $\alpha = 1$  | .孩, can 来我是all the way across 市。。There 是无人 can help 我。

en→zh,  $\alpha = 2$  | .孩的家我是这个人的市。。他是他人的到我。

en→zh,  $\alpha = 3$  | 。, 的的他是的个的, 。: 他是他人, 的。他。

---

Unsupervised token-level translation ☺

# Outline

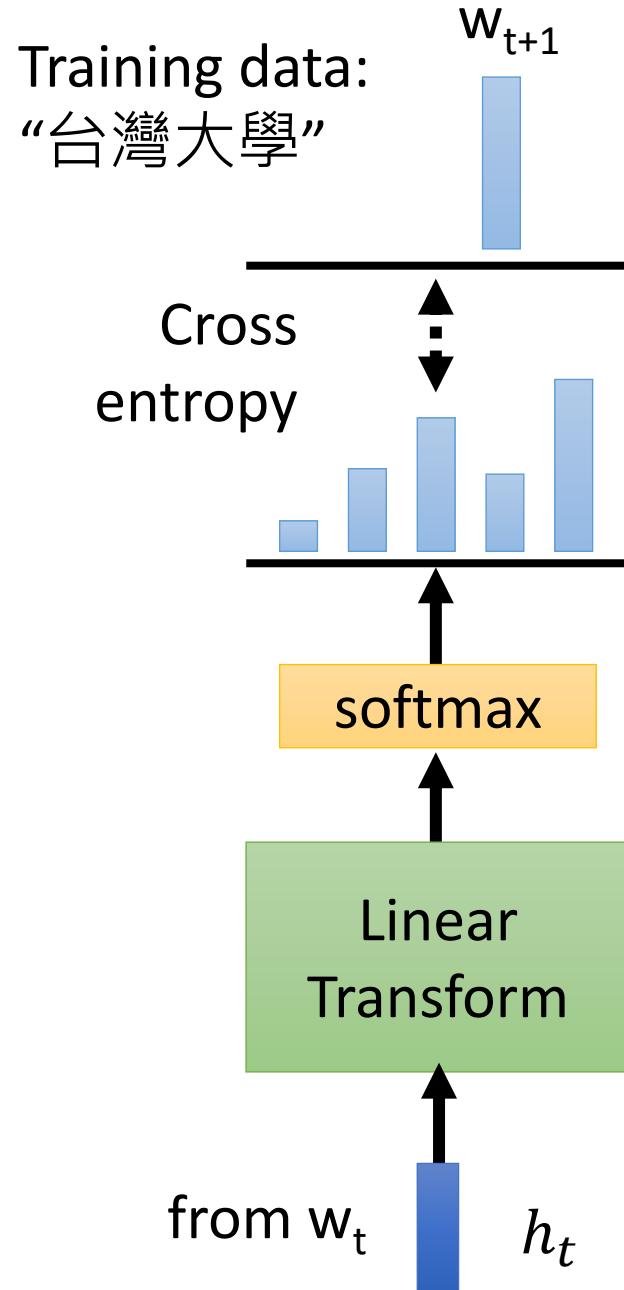
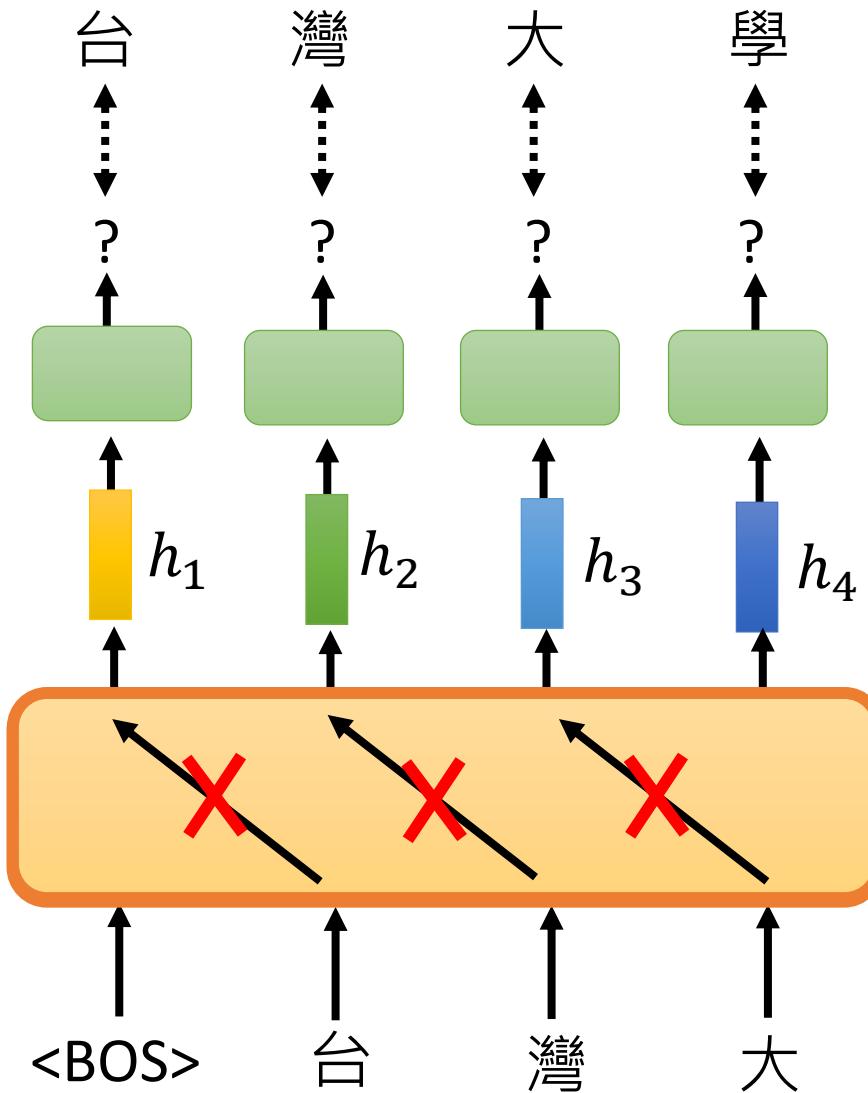


BERT series



GPT series

# Predict Next Token



# Predict Next Token

They can do generation.



PROMPT  
(WRITTEN)

*In a shocking finding, scientist discovered a herd of unicorns living in a remote, previously unexplored valley, in the Andes Mountains. Even more surprising to the researchers was the fact that the unicorns spoke perfect English.*

MODEL  
COMPLETION  
(MACHINE-  
10 TRIES)

The scientist named the population, after their distinctive horn, Ovid's Unicorn. These four-horned, silver-white unicorns were previously unknown to science.

Now, after almost two centuries, the mystery of what sparked this odd phenomenon is finally solved.

Dr. Jorge Pérez, an evolutionary biologist from the University of La Paz, and several companions, were exploring the Andes Mountains when they found a small valley, with no other animals or humans. Pérez noticed that the valley had what appeared to be a natural fountain, surrounded by two peaks of rock and silver snow.

# How to use GPT?

## 第一部份：詞彙和結構

本部份共 15 題，每題含一個空格。請就試題冊上 A、B、C、D 四個選項中選出最適合題意的字或詞，標示在答案紙上。

例：

It's eight o'clock now. Sue \_\_\_\_\_ in her bedroom.

- A. study
- B. studies
- C. studied
- D. is studying

正確答案為 D，請在答案紙上塗黑作答。

Description

A few example

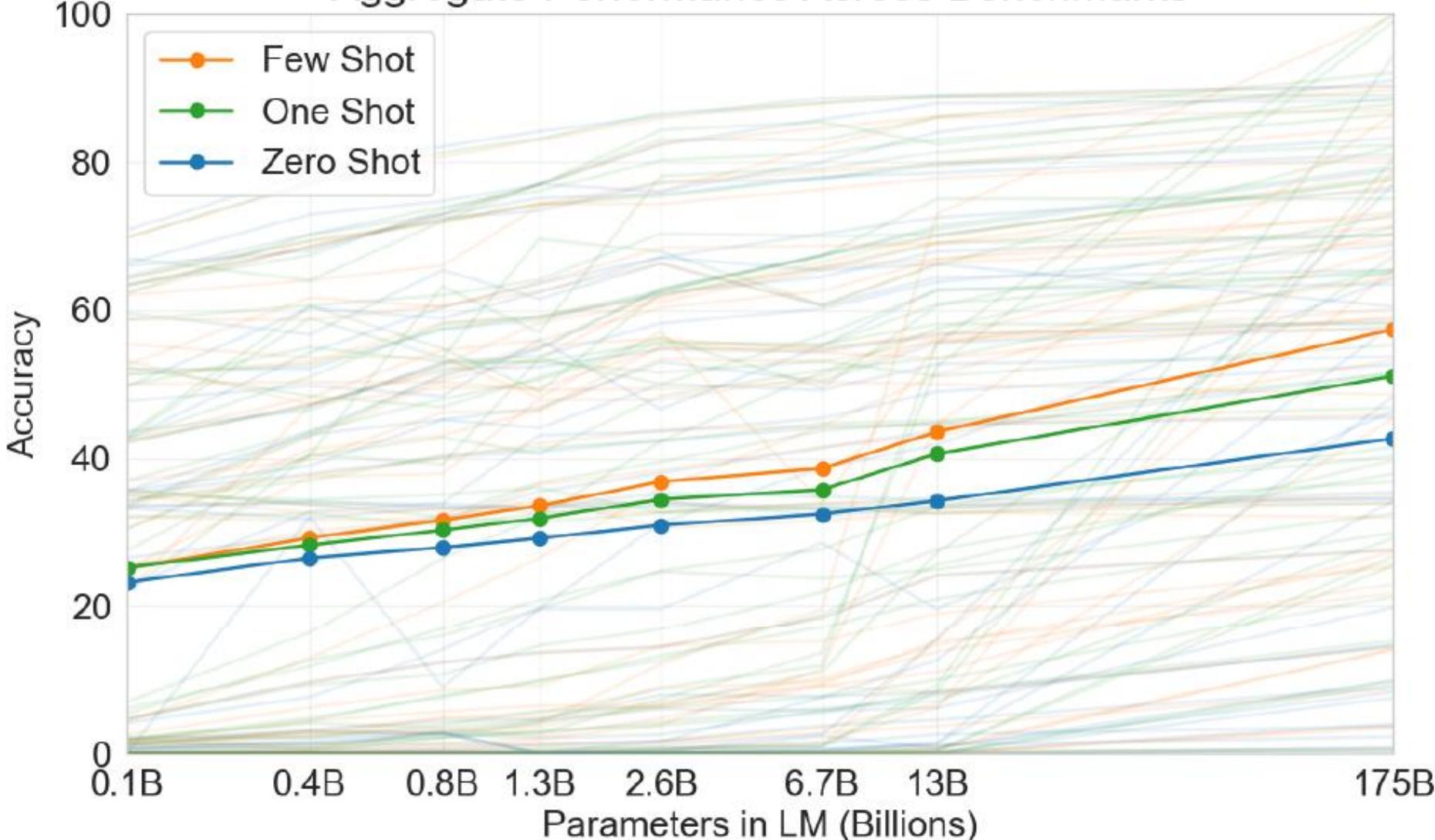
# ***“Few-shot” Learning***

(no gradient  
descent)

- 1 Translate English to French: ← task description
- 2 sea otter => loutre de mer ← examples
- 3 peppermint => menthe poivrée
- 4 plush girafe => girafe peluche
- 5 cheese => ..... ← prompt

***“In-context” Learning***

## Aggregate Performance Across Benchmarks



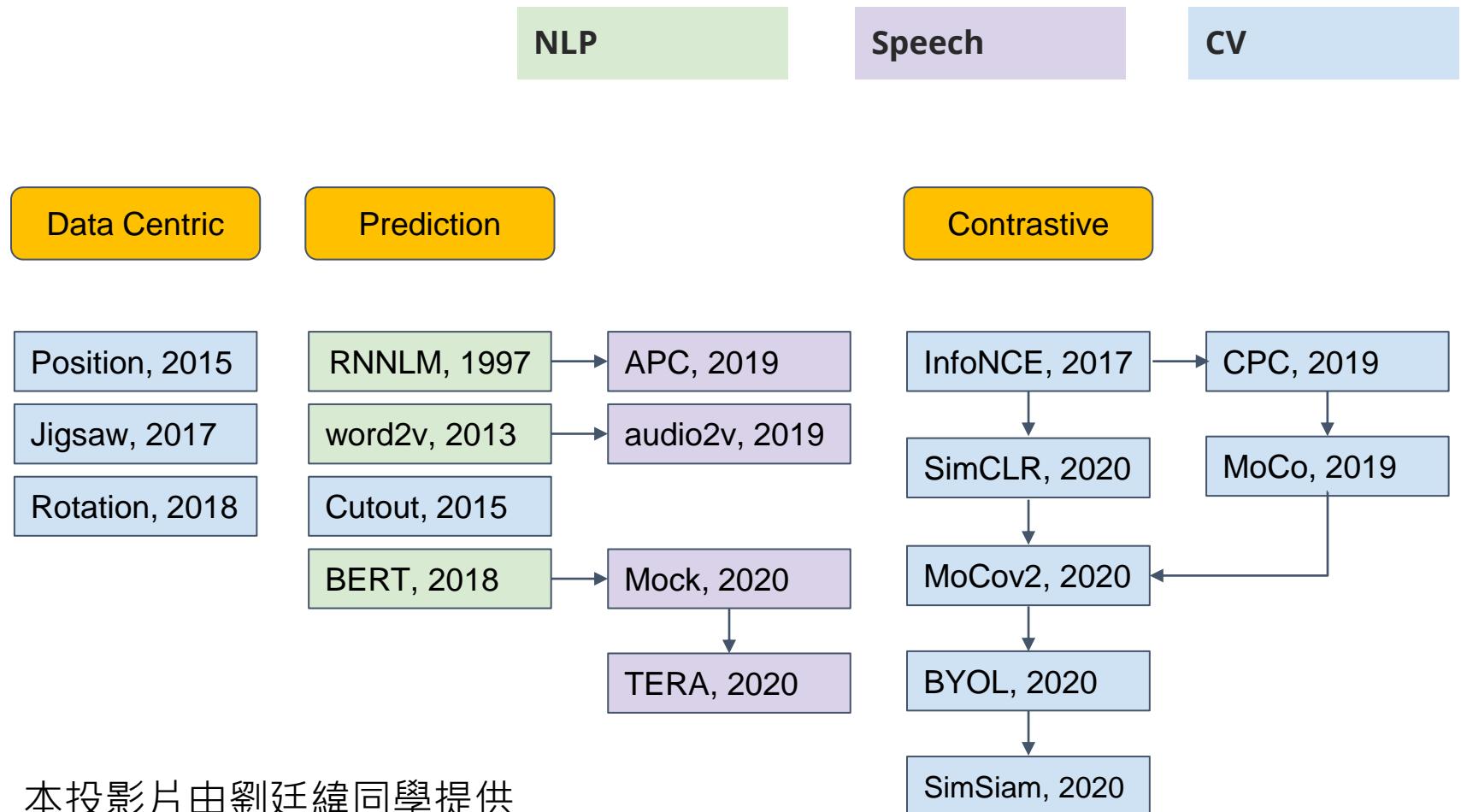
Average of **42** tasks

To learn more .....



<https://youtu.be/DOG1L9IvsDY>

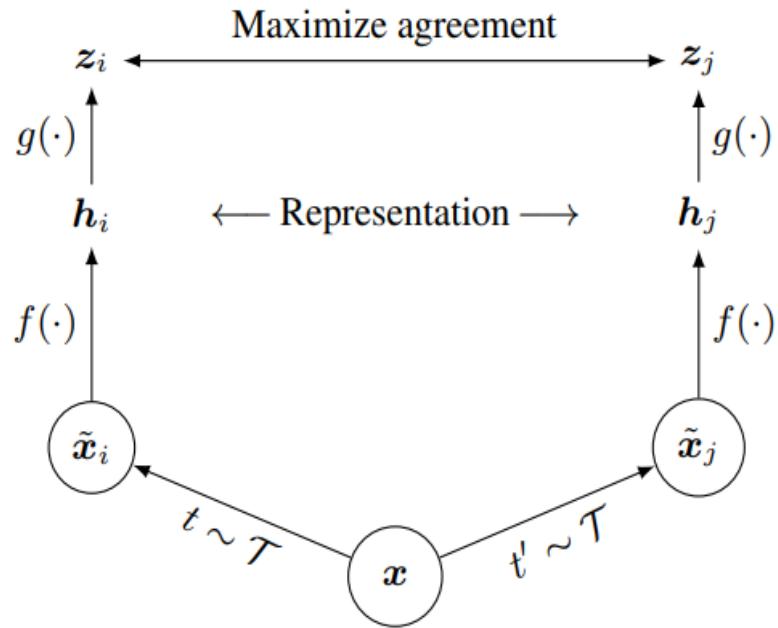
# Beyond Text



本投影片由劉廷緯同學提供

# Image - SimCLR

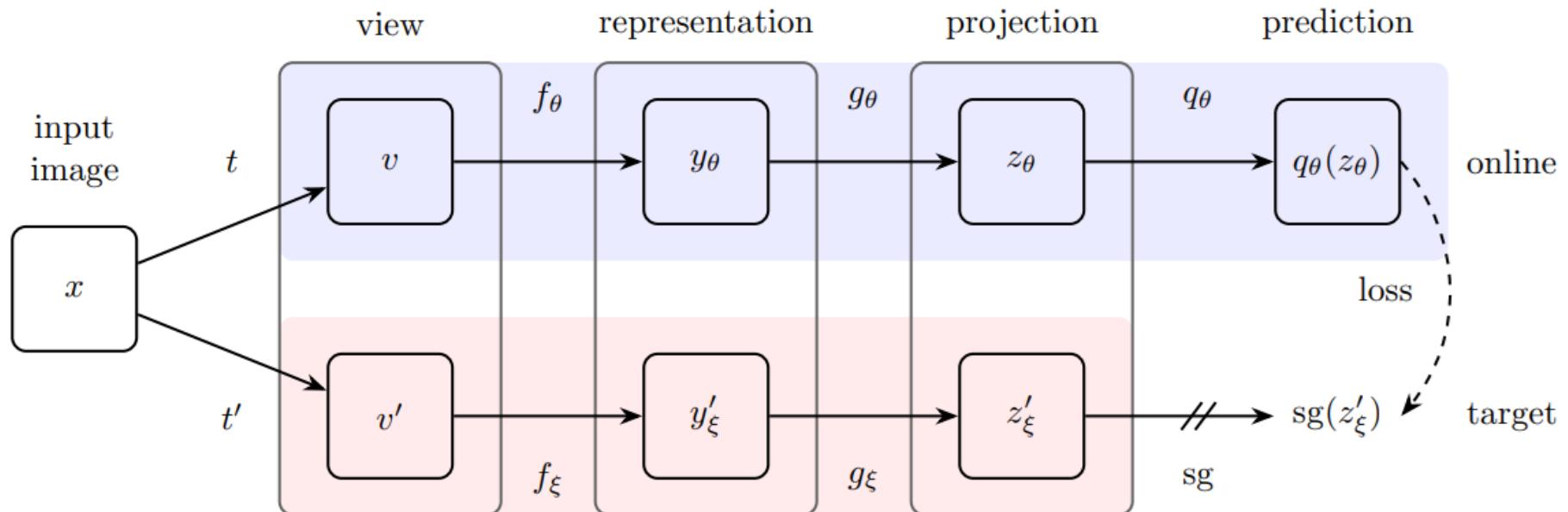
<https://arxiv.org/abs/2002.05709>  
<https://github.com/google-research/simclr>



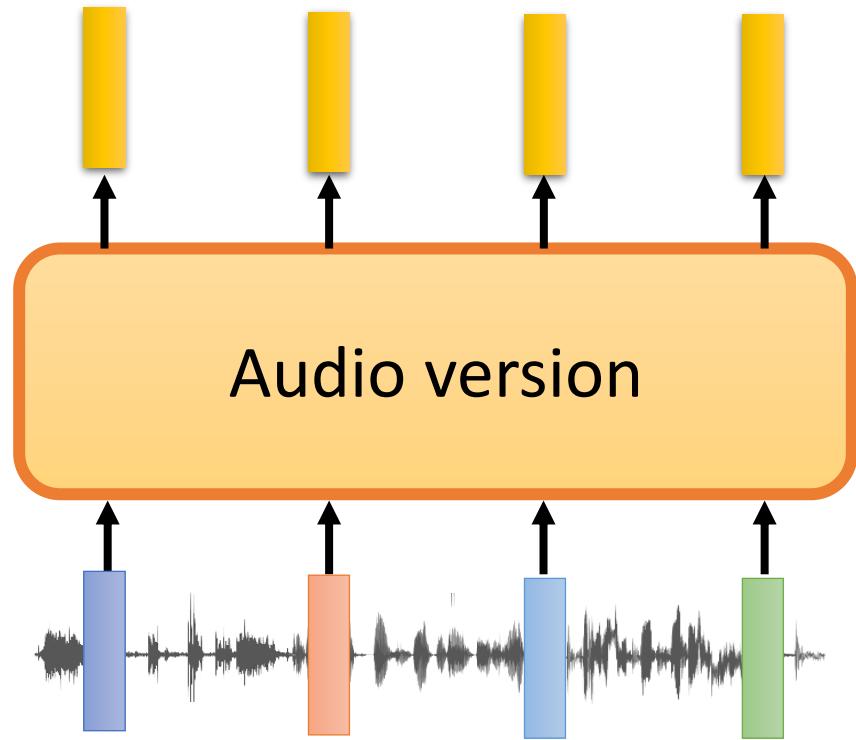
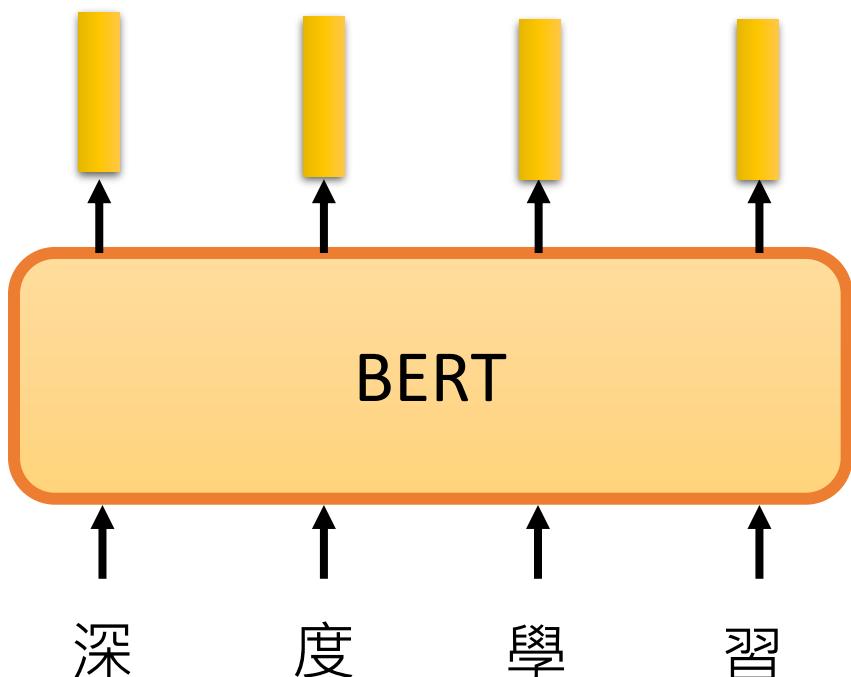
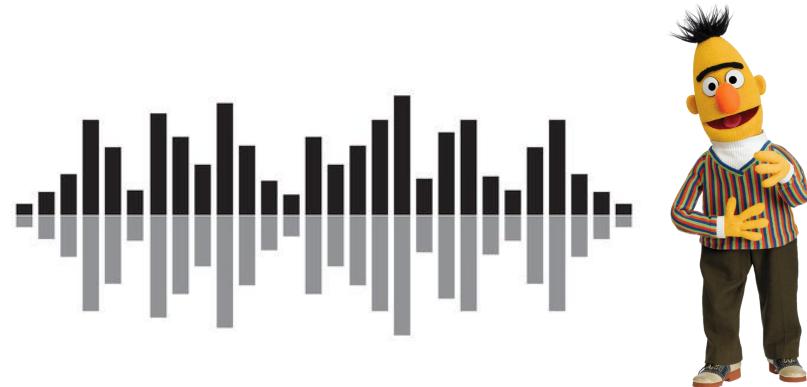
# Image - BYOL

**Bootstrap your own latent:**  
A new approach to self-supervised Learning

<https://arxiv.org/abs/2006.07733>

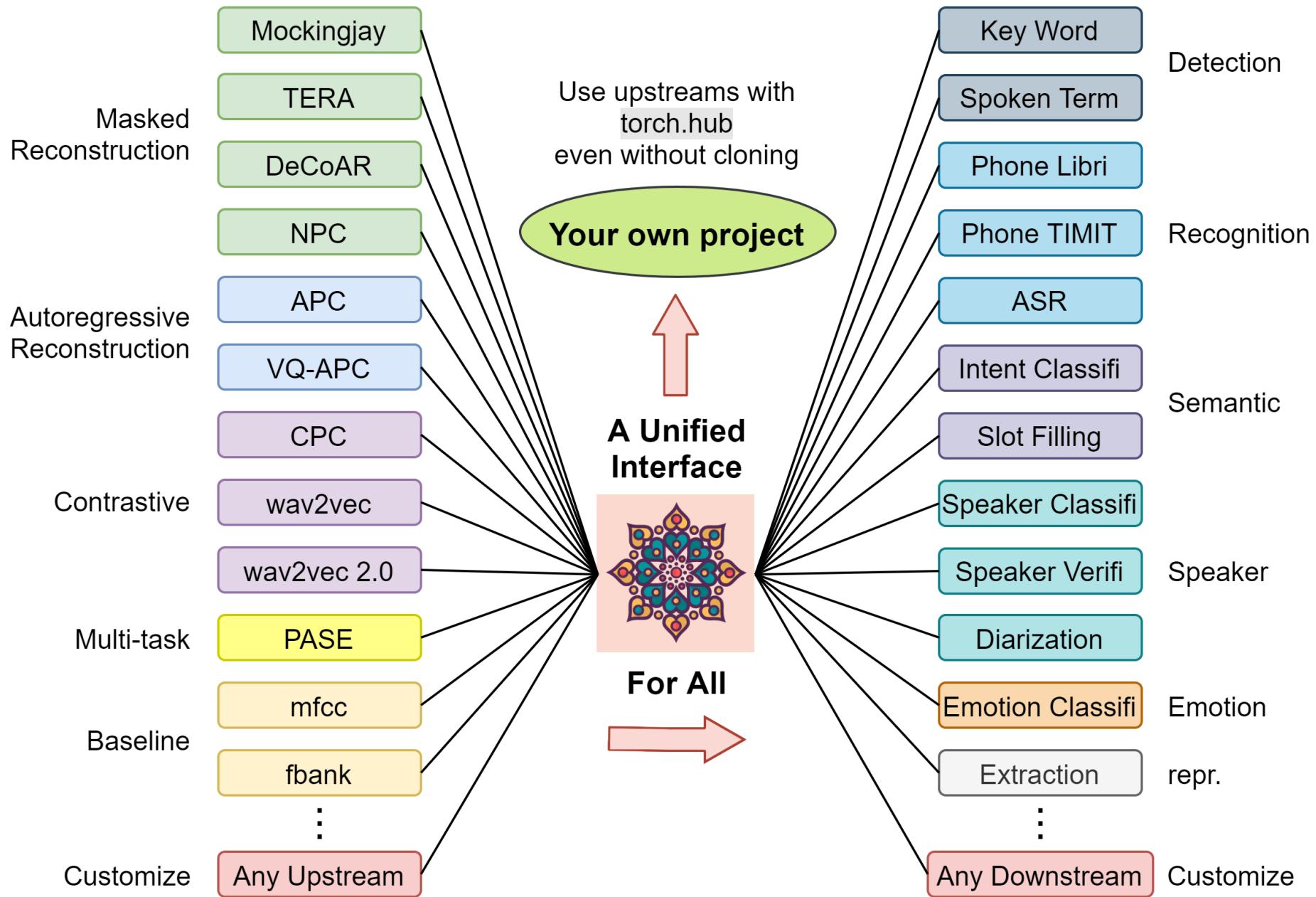


# Speech



# Speech GLUE - SUPERB

- **Speech processing Universal PERformance Benchmark**
  - Will be available soon
- **Downstream:** Benchmark with 10+ tasks
  - The models need to know how to process content, speaker, emotion, and even semantics.
- **Toolkit:** A flexible and modularized framework for self-supervised speech models.
  - <https://github.com/s3prl/s3prl>



# Appendix

(a joke)

# Predict Next Token

They can do generation.



Keaton Patti ✅ @KeatonPatti · 2019年8月13日

I forced a bot to watch over 1,000 hours of Batman movies and then asked it to write a Batman movie of its own. Here is the first page.

BATMAN

INT. TRADITIONAL BATCAVE

BATMAN stands next to his batmobile  
He's sometimes Bruce Wayne sometime

THE JOKER

I am such a freak. Society i  
You drink water, I drink ana

BATMAN

I drink bats just like a bat

BATMAN

This is now a safe city.  
punched a penguin into p

Batman looks around for his parents, b  
This makes him have anger. He fires a  
deflects it with his sick sense of hum

ALFRED, Batman's loyal batler, car

THE JOKER

I have never followed a rule  
is my rule. Do you follow? I

ALFRED

Eat a dinner, Mattress W

An explosion explodes. THE JOKER ar  
Joker is a clown but insane. Two-F

BATMAN

Alfred, give birth to Robin.

BATMAN

No! It is Two-Face and o  
They hate me for being a

Alfred begins the process since it is  
has a present in his hand. He juggles

Batman throws Alfred at Two-Face. I  
a coin. Alfred lands heads up which

THE JOKER

Happy batday, Birthman.

BATMAN (CONT'D

It is just you and I, the  
Bat versus clown. Moral,

Batman opens the present since he's a  
coupon for new parents, but is expired

4,165

5.4萬

14.3萬

↑

**BATMAN**

INT. TRADITIONAL BATCAVE

BATMAN stands next to his batmobile and uses his batcomputer.  
He's sometimes Bruce Wayne sometimes Batman. Alltimes orphan.

BATMAN

This is now a safe city. I have  
punched a penguin into prison.

ALFRED, Batman's loyal batler, carries a tray of goth ham.

ALFRED

Eat a dinner, Mattress Wayne.

An explosion explodes. THE JOKER and TWO-FACE enter the cave.  
Joker is a clown but insane. Two-Face is a man but attorney.

律師

BATMAN

No! It is Two-Face and One-Face.  
They hate me for being a bat.

Batman throws Alfred at Two-Face. Two-Face flips Alfred like  
a coin. Alfred lands heads up which means Two-Face goes home.

BATMAN (CONT'D)

It is just you and I, the Joker.  
Bat versus clown. Moral enemies.

THE JOKER

I am such a freak. Society is bad.  
You drink water, I drink anarchy.

混亂

BATMAN

I drink bats just like a bat would!

Batman looks around for his parents, but they are still dead.  
This makes him have anger. He fires a batrocket. The Joker  
deflects it with his sick sense of humor. A clownly power.

THE JOKER

I have never followed a rule. That  
is my rule. Do you follow? I don't.

BATMAN

Alfred, give birth to Robin.

Alfred begins the process since it is his job. The Joker now  
has a present in his hand. He juggles it over to Batman.

THE JOKER

Happy batday, Birthman.

Batman opens the present since he's a good guy. It contains a  
coupon for new parents, but is expired. This is a Joker joke.

I forced a bot to watch over 1,000 hours of XXX  
是一個梗!

人在模仿機器模仿人!!!



Keaton Patti ✅

@KeatonPatti

I forced a bot to watch over 1,000 hours  
of Olive Garden commercials and then

ask

con

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/E GARDEN

OLIVE G

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Keaton Patti ✅

@KeatonPatti

I forced a bot to watch over 1,000  
episodes of Jerry Springer and then

aske

Here



Keaton Patti ✅

@KeatonPatti

I forced a bot to watch over 1,000 hours  
of the Saw movies and then asked it to  
write a Saw movie of its own. Here is the  
first page.