

Machine Translation



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Language Technologies Institute
Machine Learning Department

MT Marathon 2012
September 3, 2012

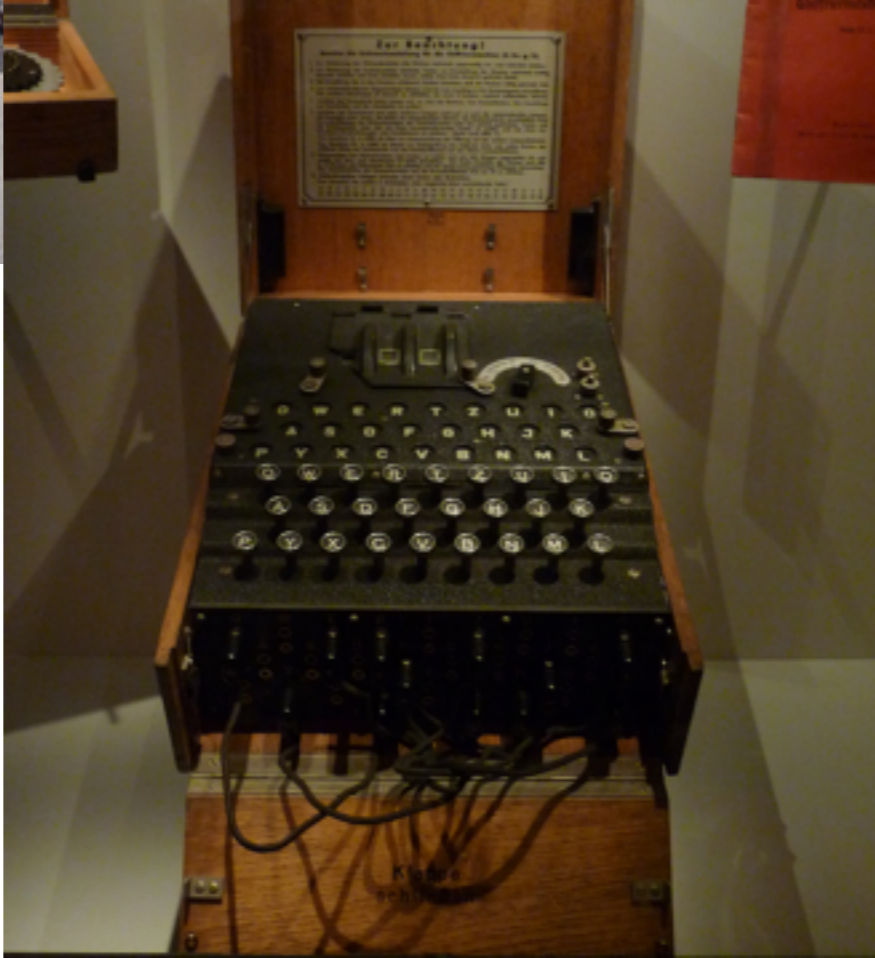
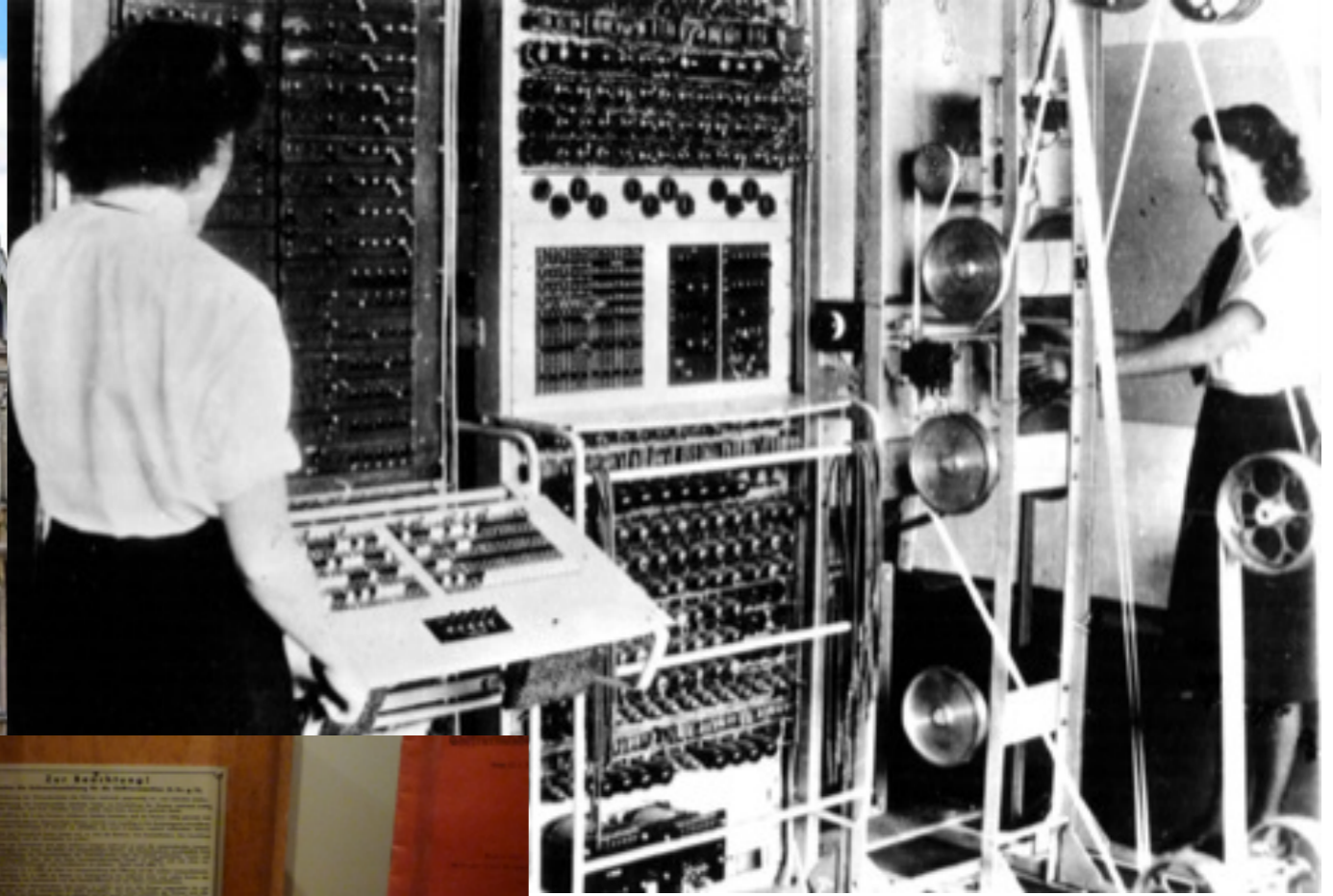


Carnegie Mellon



Overview

- A Brief History of MT
- Modeling: Language & Translation
- Using MT
- Evaluating MT
- Coffee



MT Timeline

- 1940s - WW2 code breaking
- 1947 - Weaver letter outlining translation as a problem in cryptography
- 1954 - Georgetown Experiments showed “promise” of Russian-English MT
- 1966 - ALPAC report shifts funding to basic research in computational linguistics
- 1968 - MT company SYSTRAN founded (still in existence)
- 1970s - advances in formal languages and automata theory; development of *statistical speech recognition* techniques at IBM and Princeton
- 1993 - Weaver’s model of translation prototyped by IBM; **statistical revolution**
- 1999 - Open source reimplementations of IBM models
- 2000s - Major modeling advances, rediscovery of syntax, large scale funding
- 2006 - Open source Moses decoder development begins
- 2006 - Google Translate launches

One naturally wonders if the problem of translation could conceivably be treated as a problem in cryptography. When I look at an article in Russian, I say: *'This is really written in English, but it has been coded in some strange symbols. I will now proceed to decode.'*



Warren Weaver to Norbert Wiener, March, 1947



Claude Shannon. “A Mathematical Theory of
Communication” 1948.

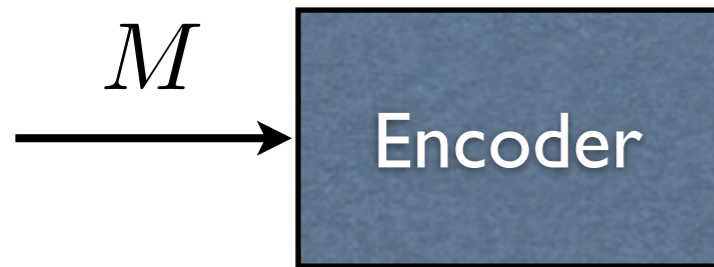
M



Message



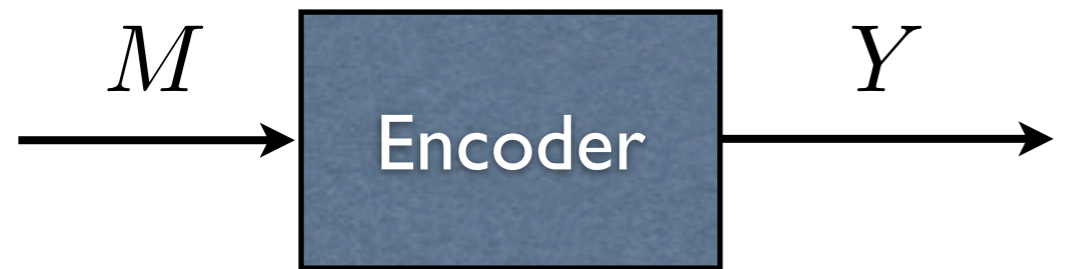
Claude Shannon. "A Mathematical Theory of Communication" 1948.



Message



Claude Shannon. "A Mathematical Theory of Communication" 1948.



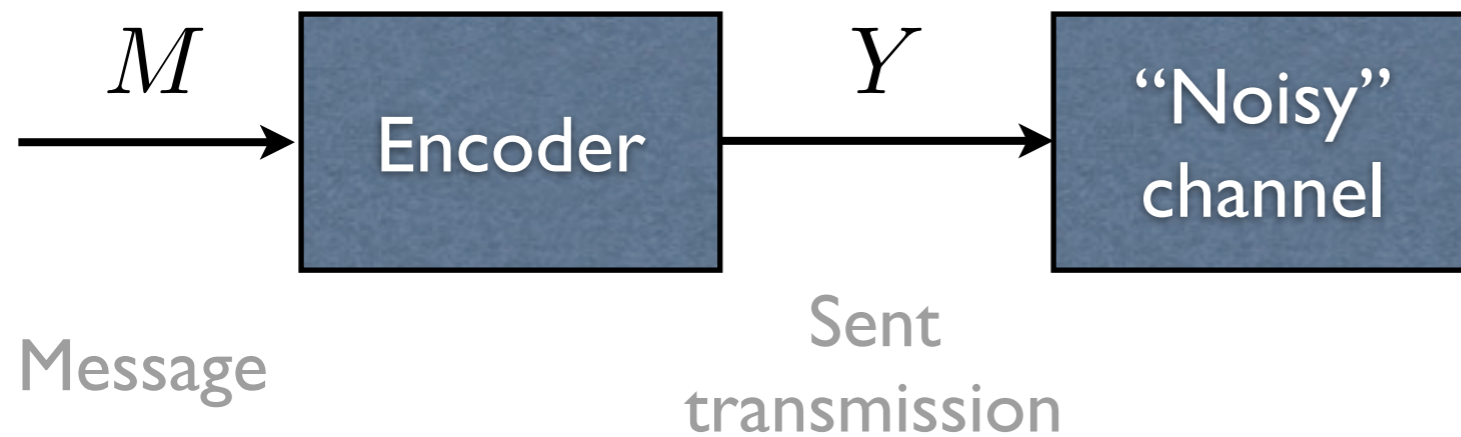
Message

Sent
transmission

$$p(y)$$



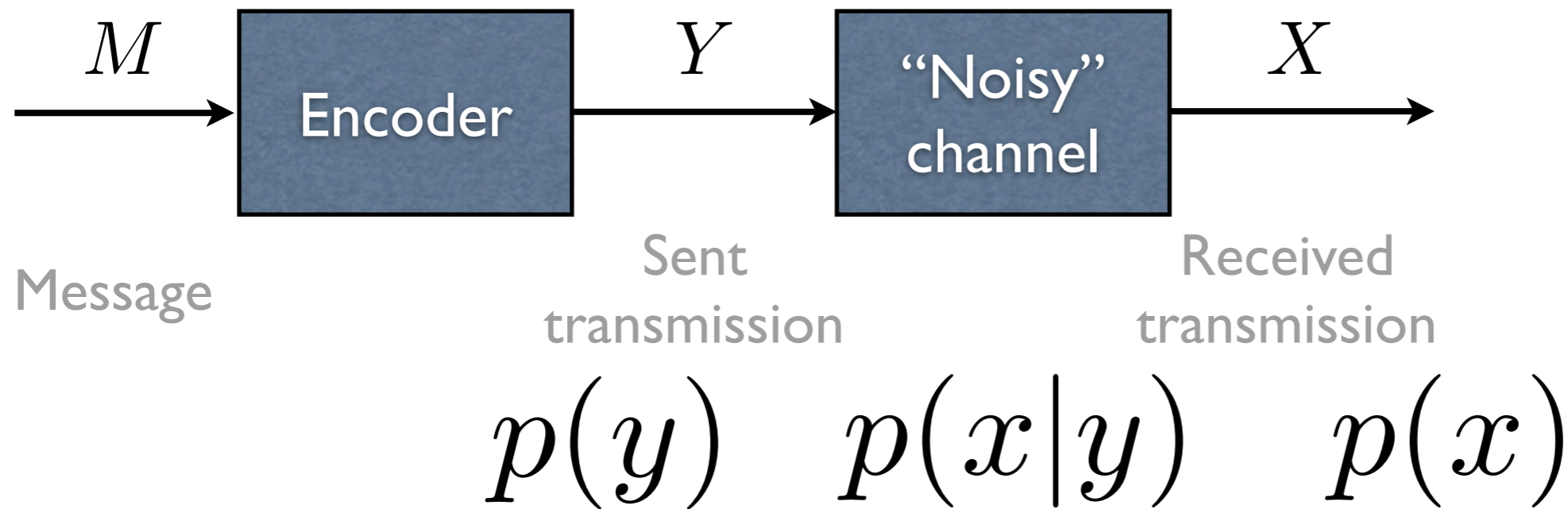
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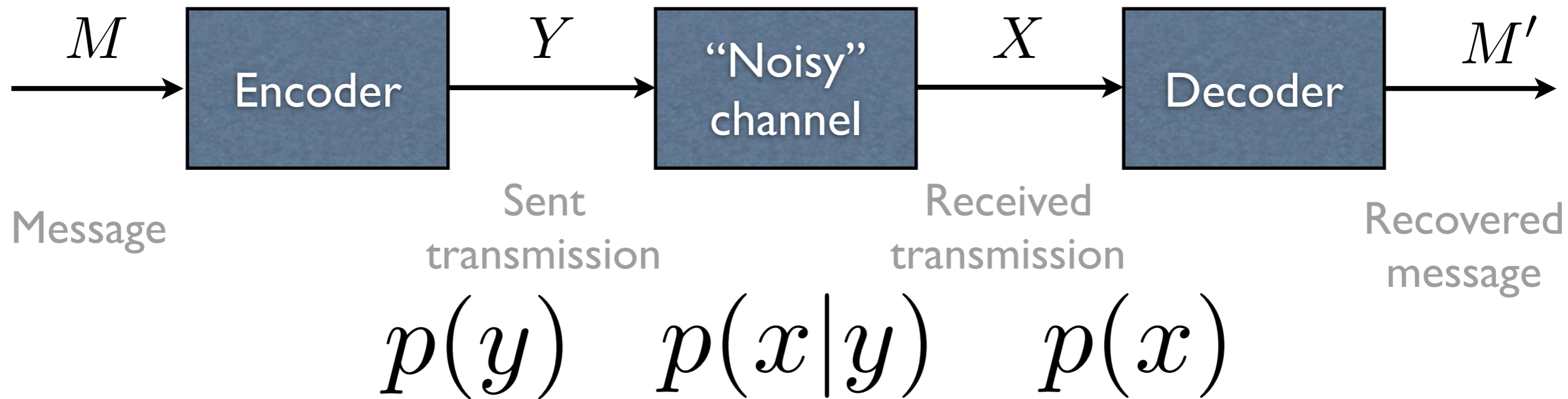
$$p(y) \quad p(x|y)$$



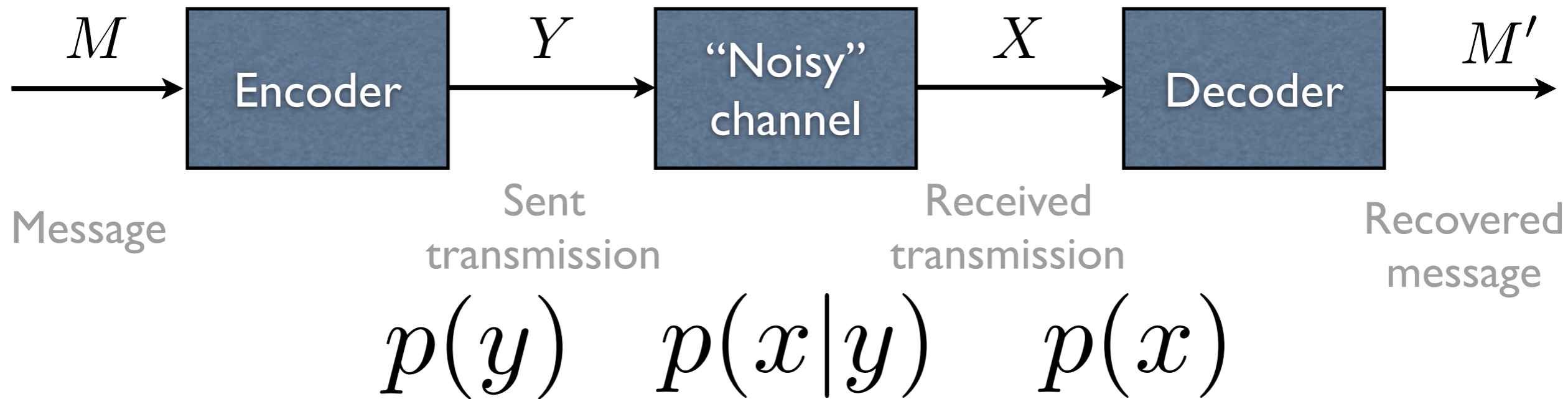
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$p(y)$ $p(x|y)$ $p(x)$



Claude Shannon. "A Mathematical Theory of Communication" 1948.



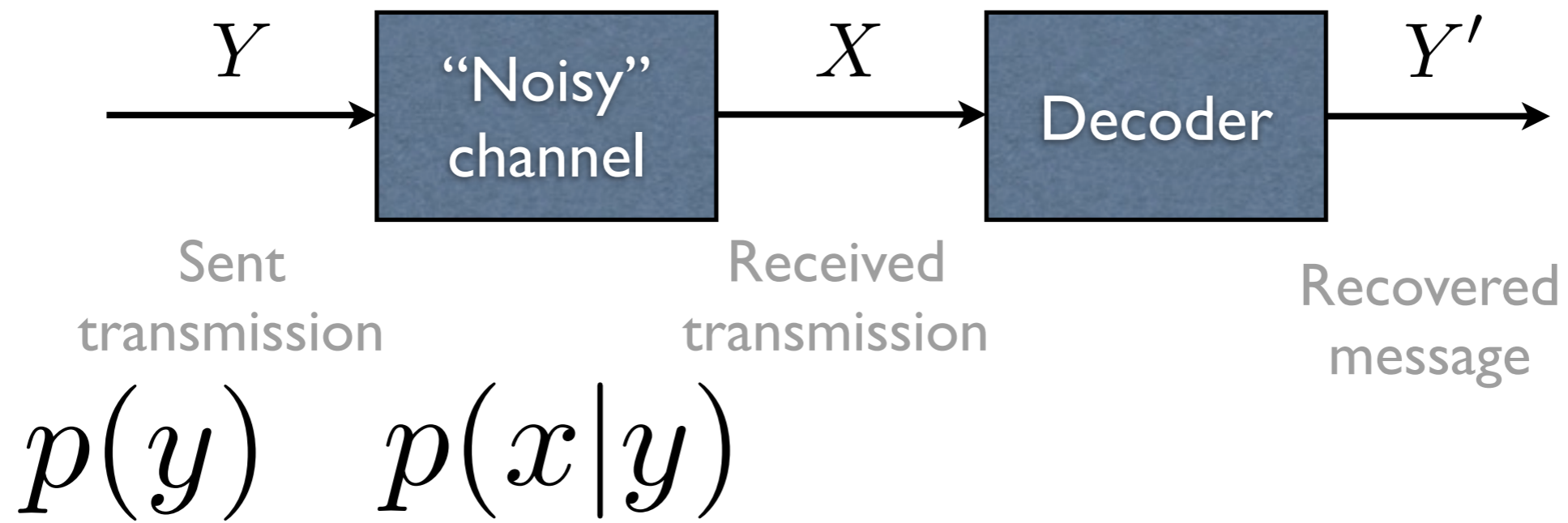
$$p(y) \quad p(x|y)$$

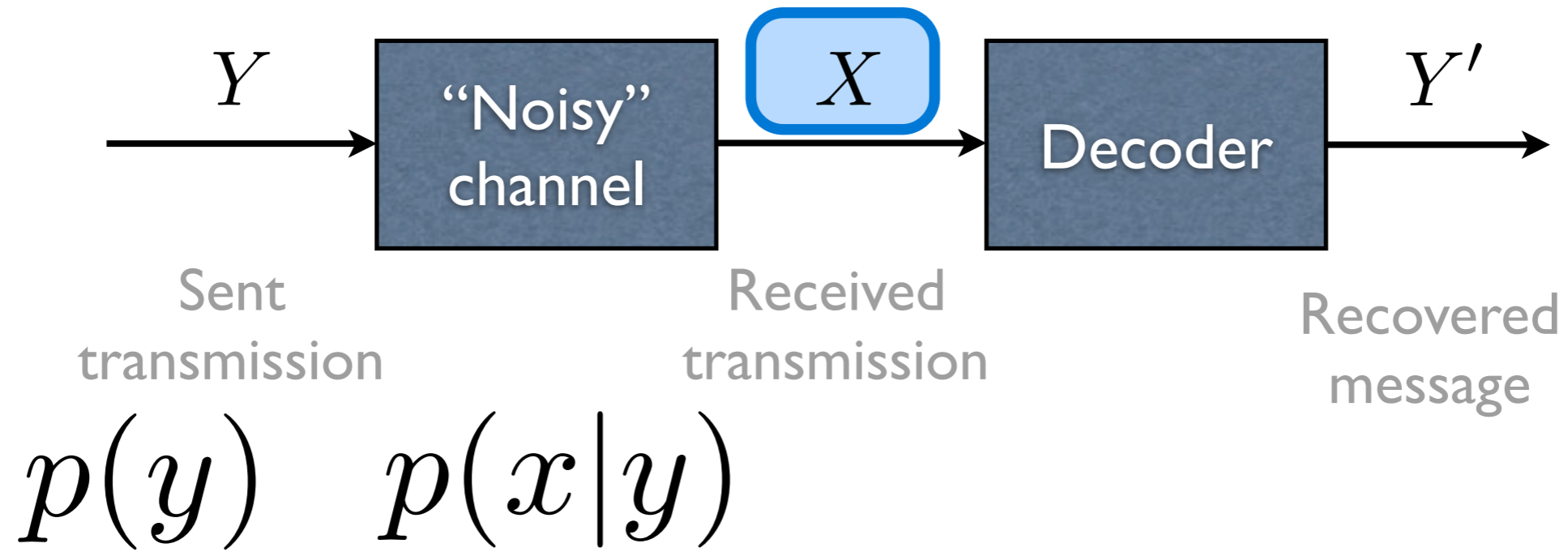
Shannon's theory tells us:

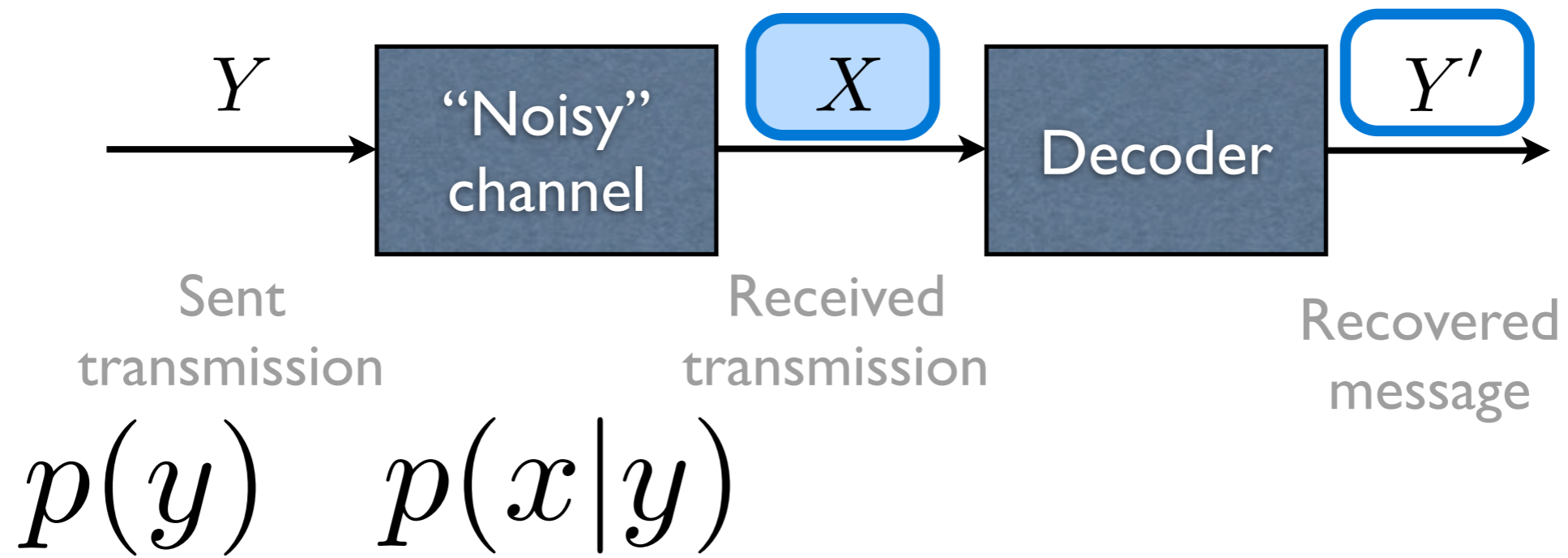
- 1) how much data you can send
- 2) the limits of compression
- 3) why your download is so slow
- 4) how to translate

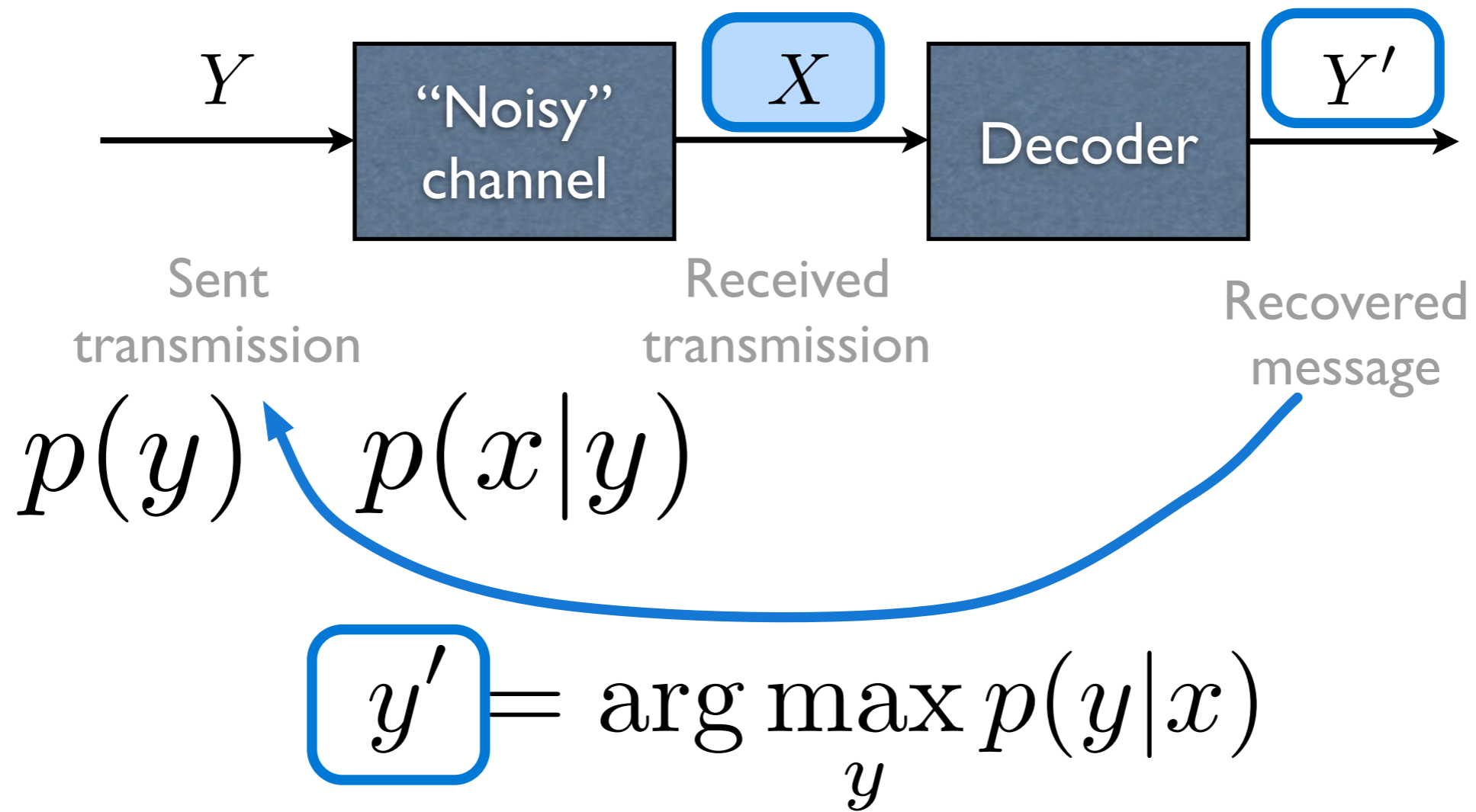


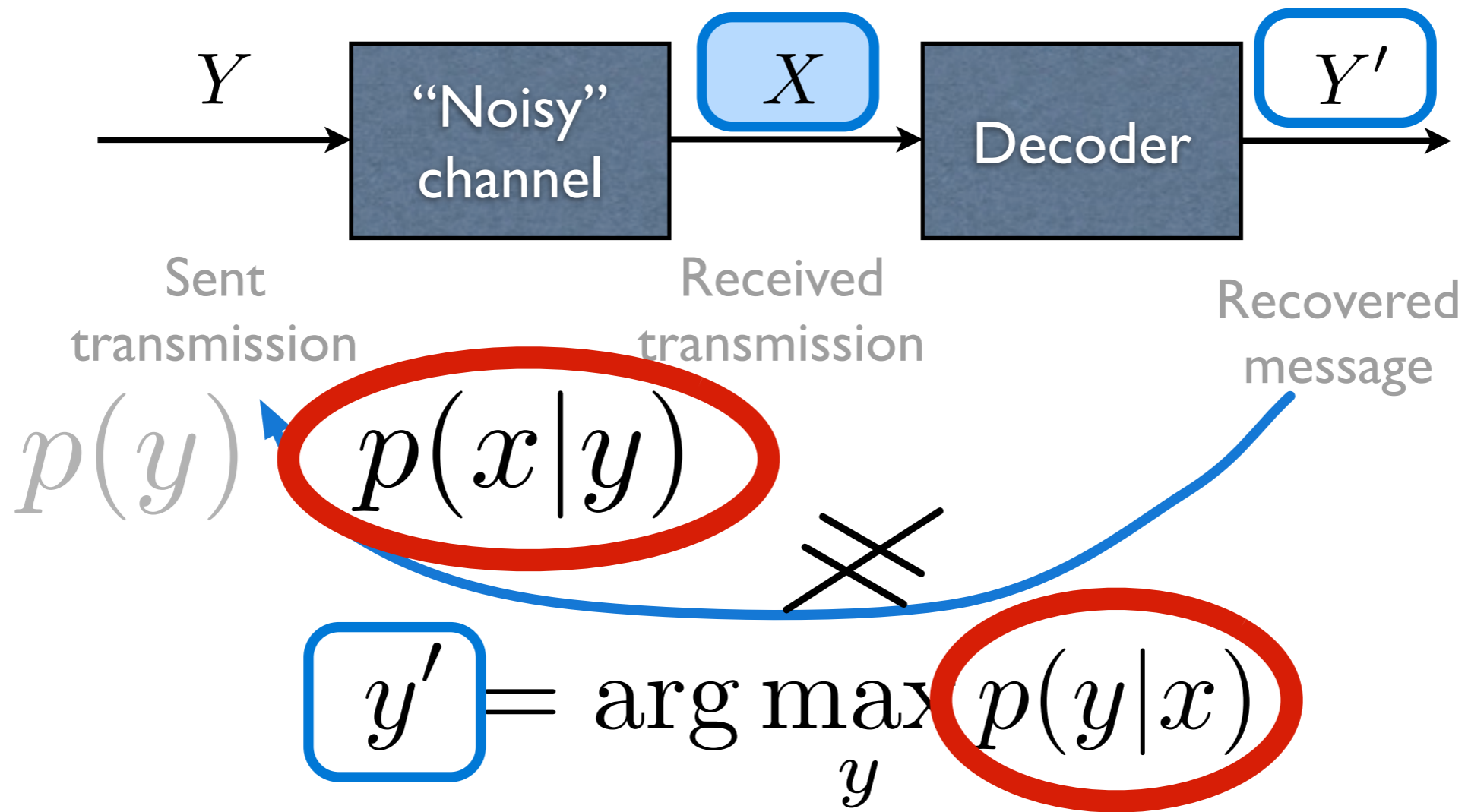
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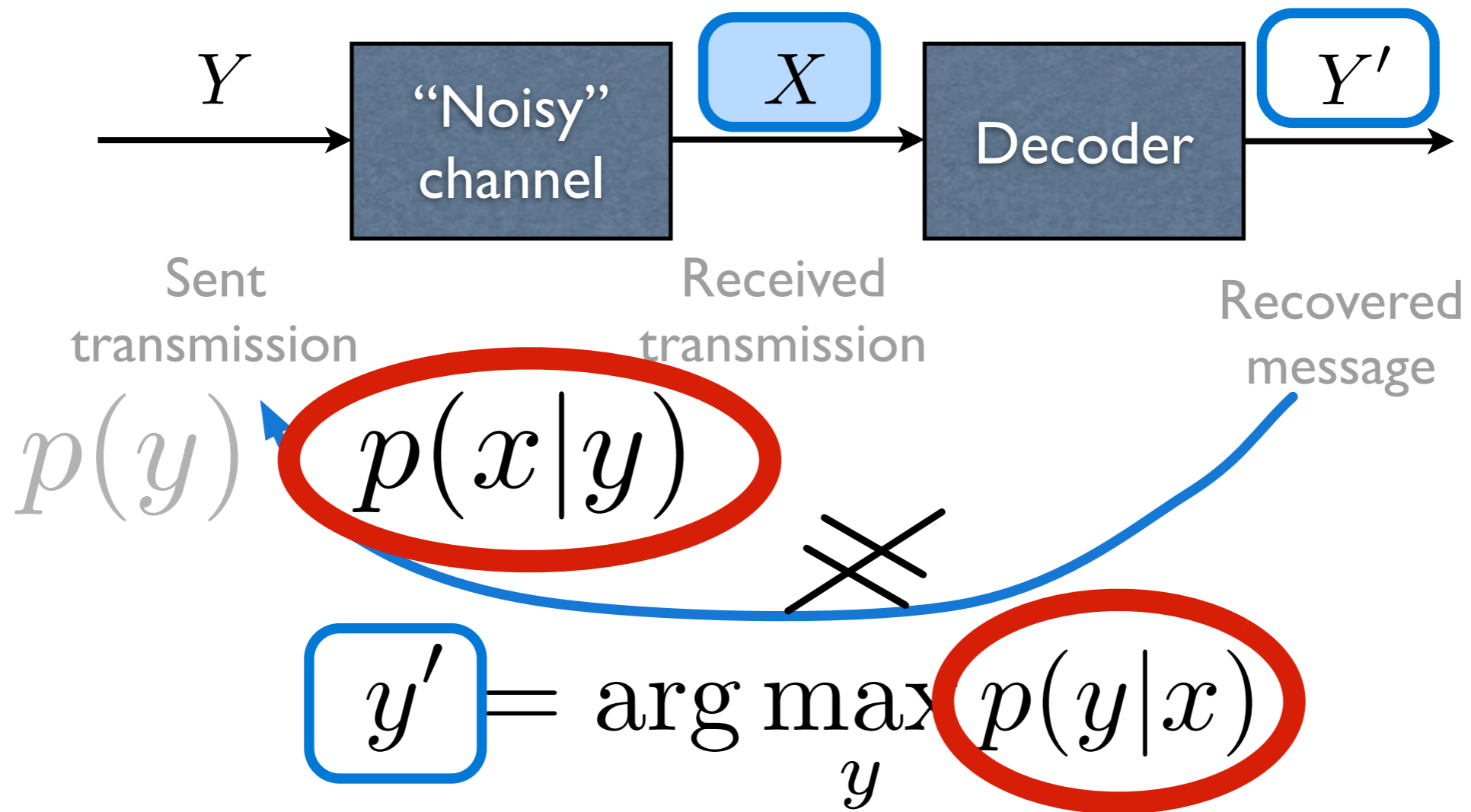




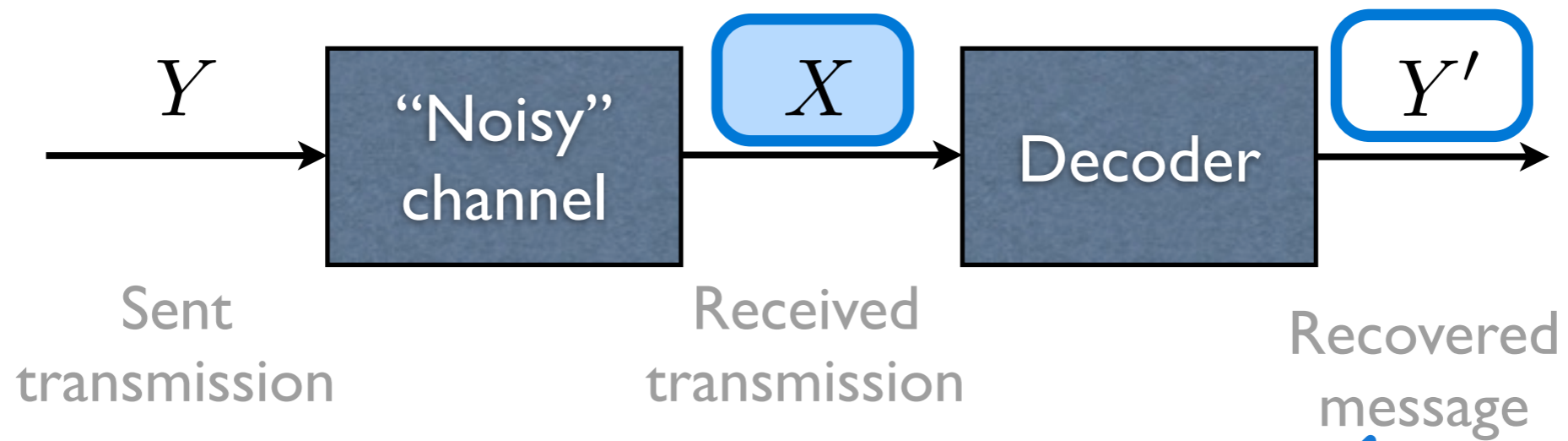






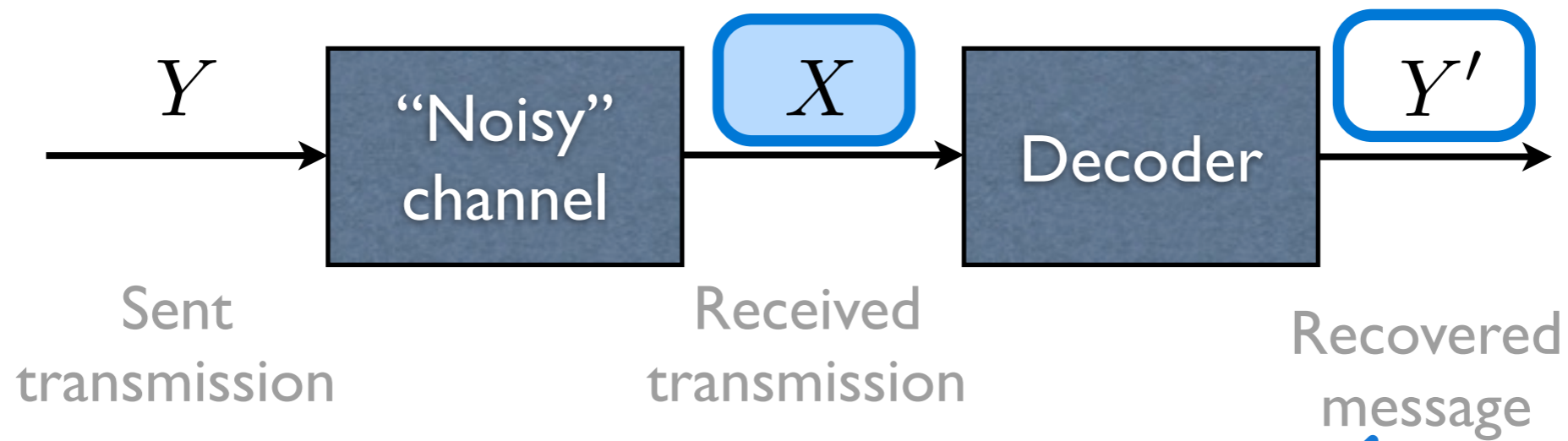


I can help.



$$y' = \arg \max_y p(y|x)$$

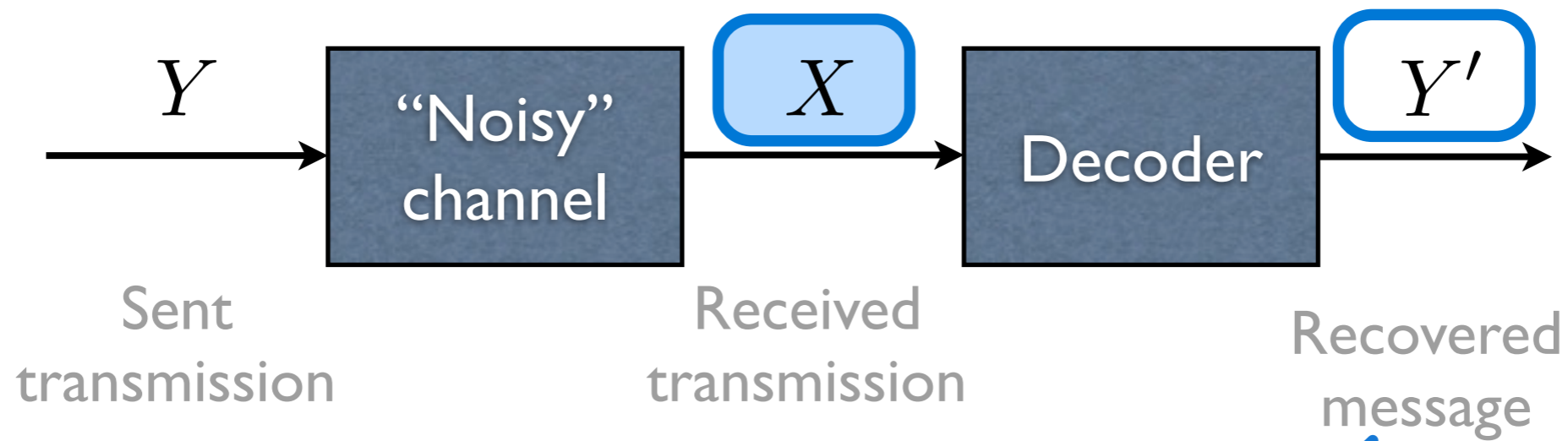
$$= \arg \max_y \frac{p(x|y)p(y)}{p(x)}$$



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$$= \arg \max_y \frac{p(x|y)p(y)}{p(x)}$$

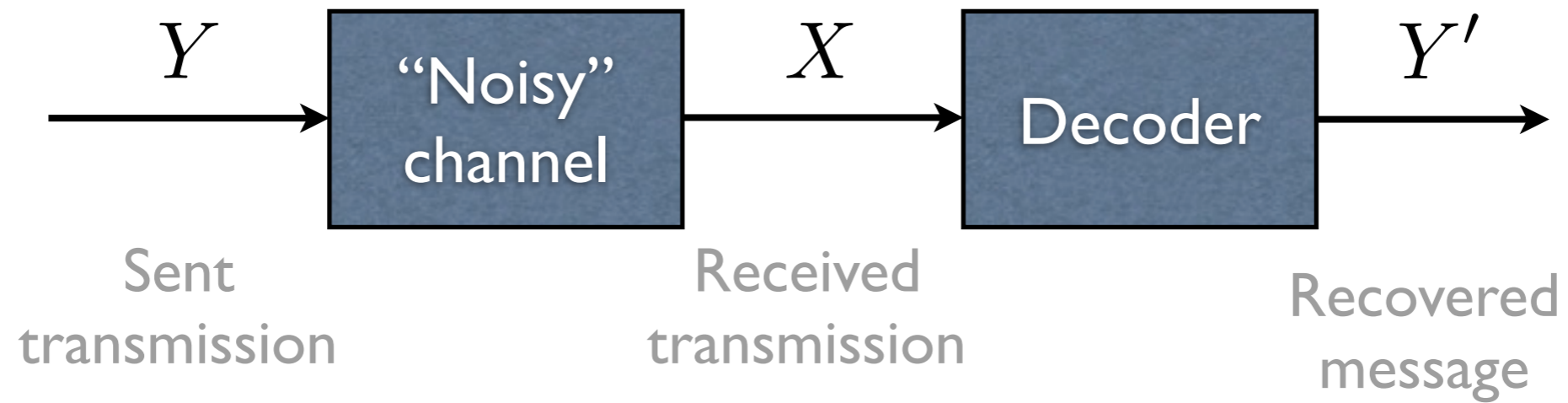
Denominator doesn't depend on y .



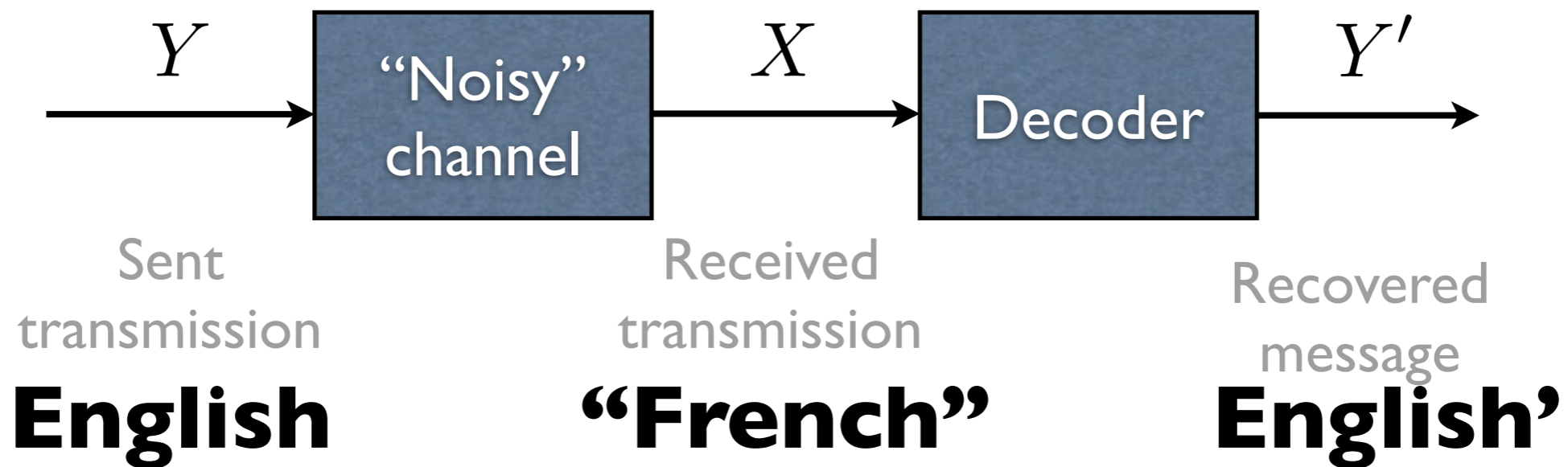
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$$= \arg \max_y p(x|y)p(y)$$

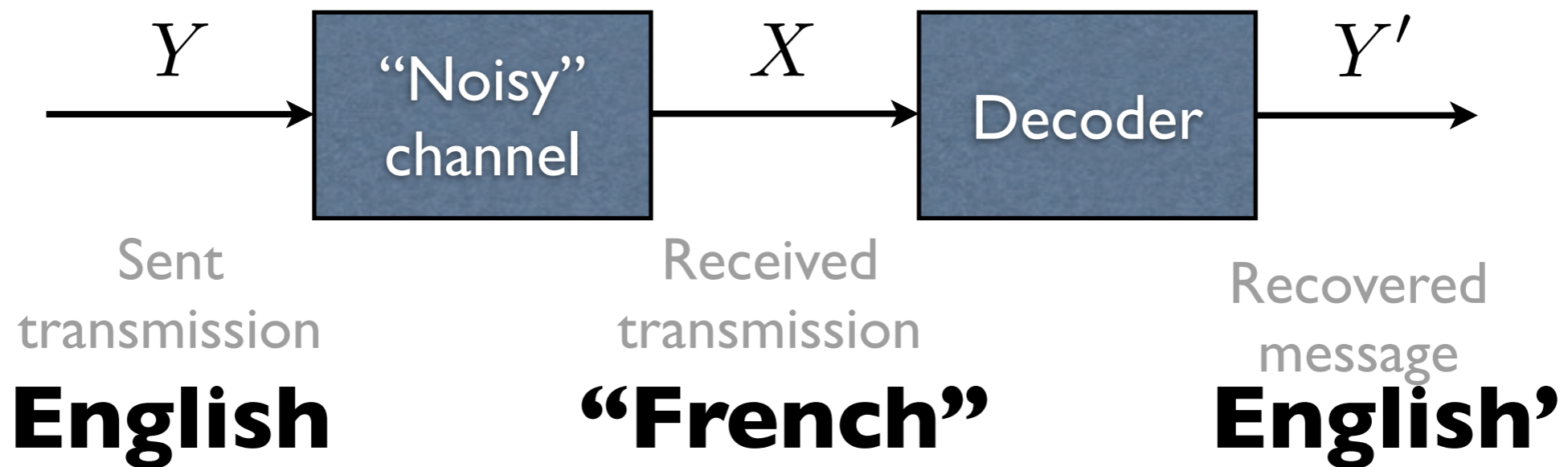


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~~$$y' = \arg \max_y p(x|y)p(y)$$~~

$$e' = \arg \max_e p(\mathbf{f}|\mathbf{e})p(\mathbf{e})$$

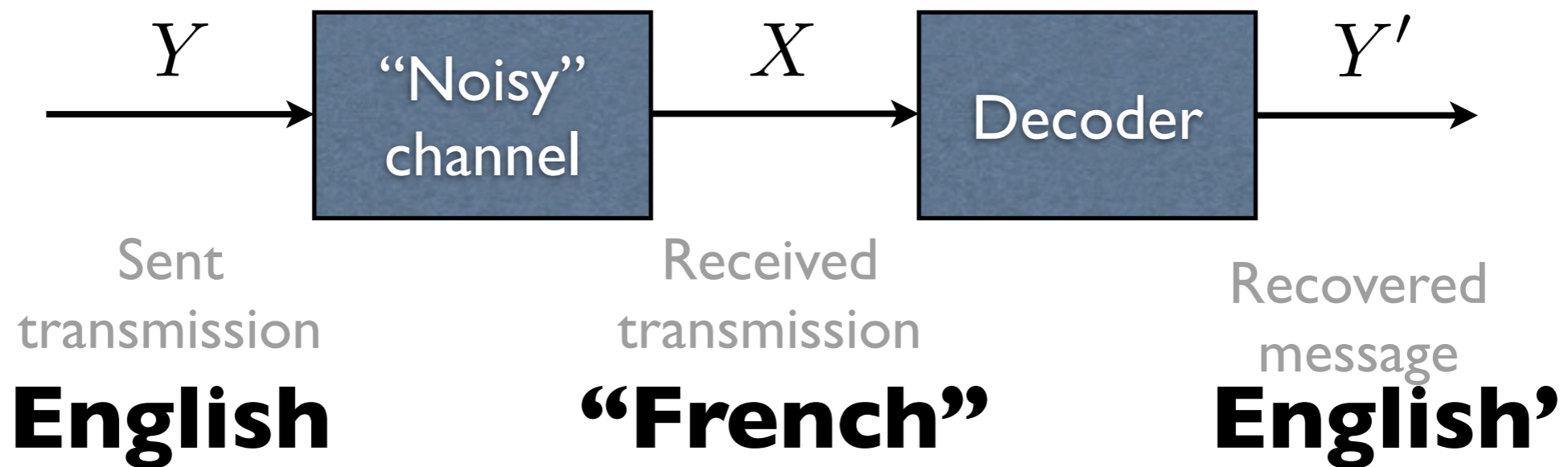


~~$$y' = \arg \max_y p(x|y)p(y)$$~~

$$e' = \arg \max_e p(\mathbf{f}|\mathbf{e})p(\mathbf{e})$$



translation model



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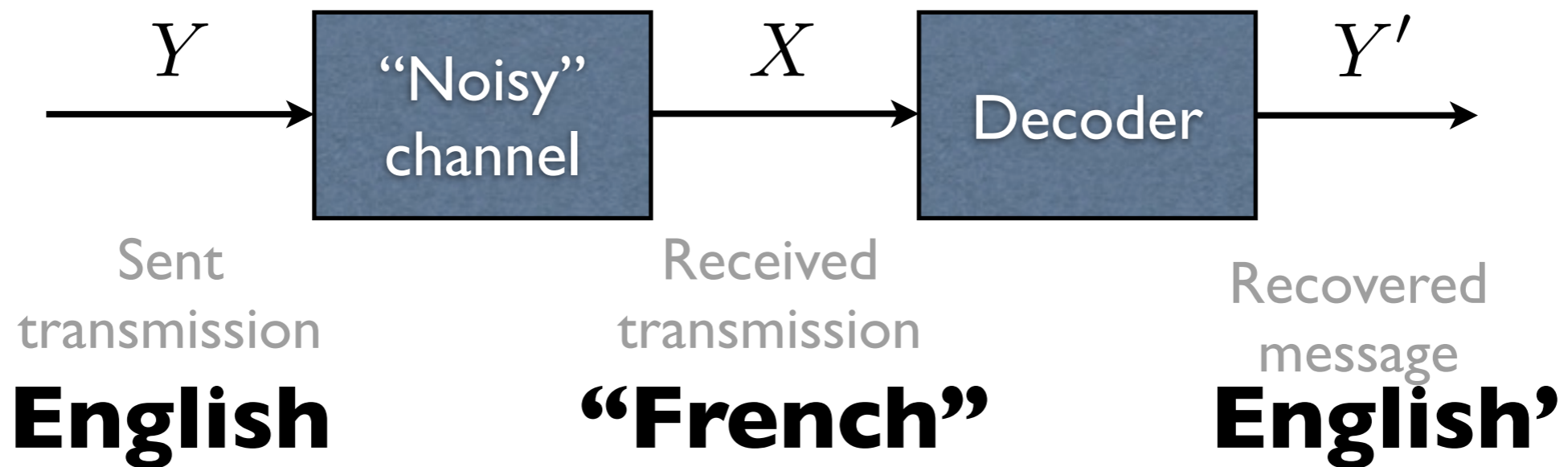
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translation model



language model



~~$$y' = \arg \max_y p(x|y)p(y)$$~~

$$e' = \arg \max_e p(\mathbf{f}|\mathbf{e})p(\mathbf{e})$$



translation model



language model

Other noisy channel applications: OCR, speech recognition, spelling correction...

Division of labor

- **Translation model**
 - probability of translation *back* into the source
 - ensures **adequacy** of translation
- **Language model**
 - is a translation hypothesis “good” English?
 - ensures **fluency** of translation

The Big Question in MT

The Big Question in MT

- **How do we *design* language and translation models?**

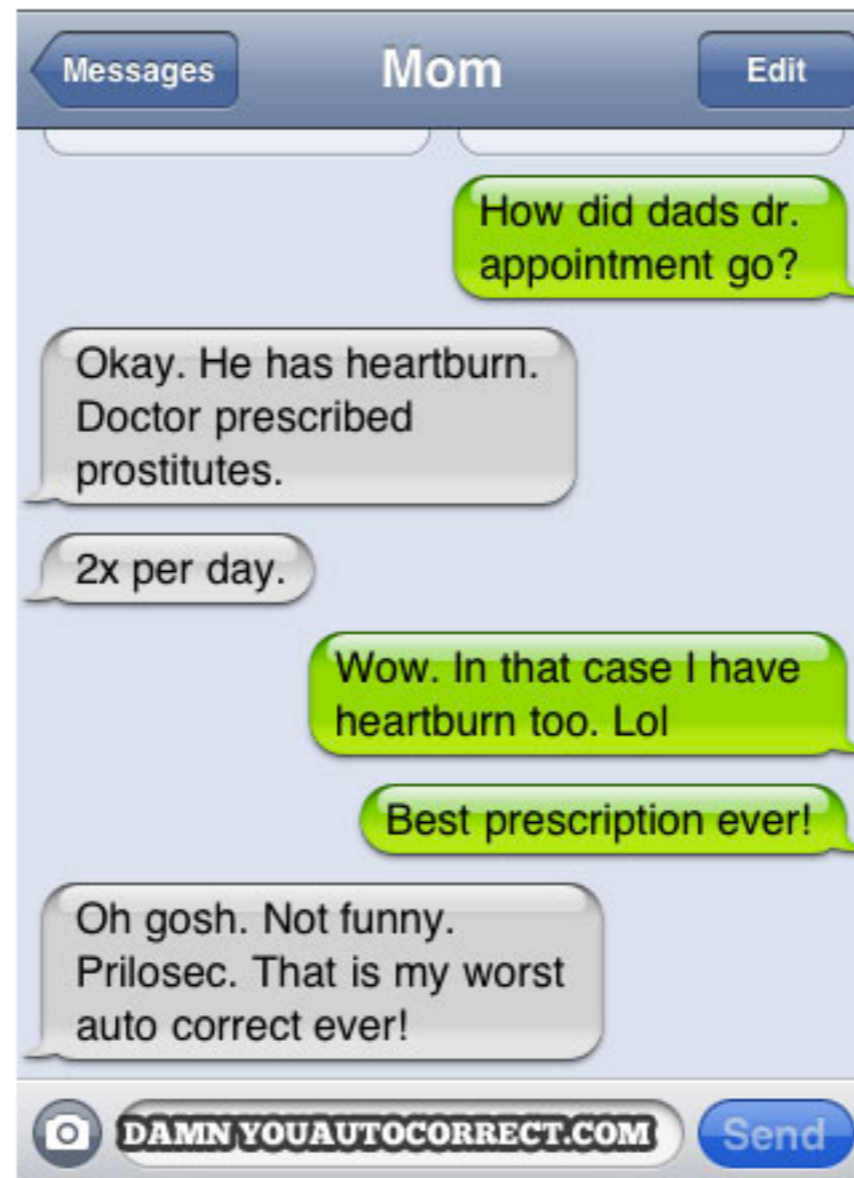
The Big Question in MT

- **How do we *design* language and translation models?**
- Two (usually competing) considerations
 - Is the model **correct**?
 - Is prediction (*inference*) **tractable**?
 - Also: is there data to learn the parameters?

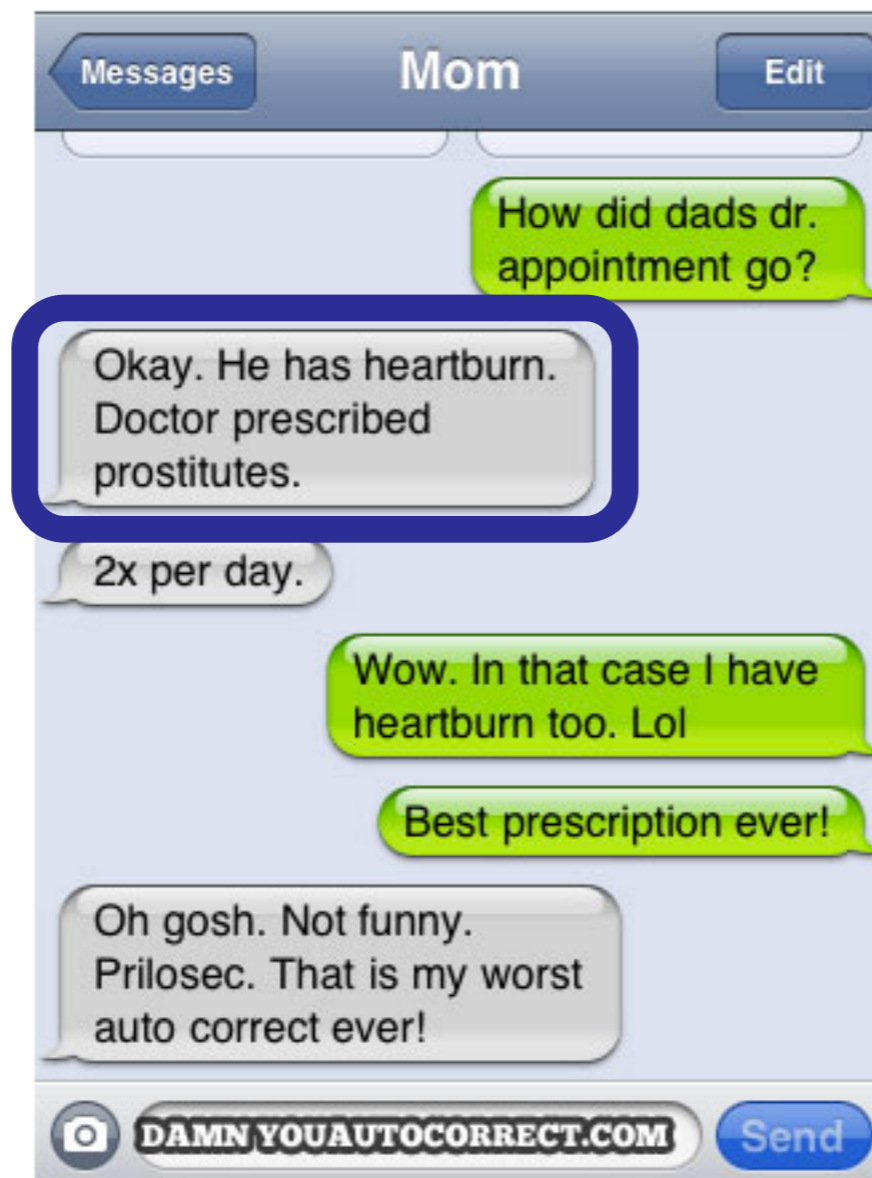
Language Modeling

- Two related, but different questions:
 - Is a string of words grammatical or not?
 - Is a string of grammatical words semantically coherent?
- We usually adopt a statistical approach:
 - What is the **probability** of a sentence in some language?
 - **Modeling challenge:** there are an *infinite number* of grammatical sentences in any language

DAMN YOU, AUTO CORRECT!



DAMN YOU, AUTO CORRECT!



Open Problems

- N -gram models have billions or trillions of parameters
 - Do we really need all of these?
 - If we do, how do we efficiently represent them?
- How do we efficiently reason with LMs?
- Can we come up with a better representation for words?
- Can we leverage *syntactic* information to improve language models?
- LMs were developed for English: ***how should they change when we model different languages?***

English:

I have a bad headache

Chukchi (Siberian language):

Təmeyŋəlevtpəytərəkən

English:

I have a bad headache

Chukchi (Siberian language):

Təmeyŋəlevtpəytərəkən



Aggultinative and polysynthetic languages have rich word-formation processes.

Translation Modeling

- Modeling task: Is a string of words \mathbf{e} (in the target language) a meaning-preserving translation of a string of words \mathbf{f} (in the source)?
- **Modeling challenges:**
 - There are an infinite number of sentences
 - How do we learn parameters of the models?

In der Innenstadt explodierte eine Autobombe

- **Factor problem into (conditionally) independent parts**

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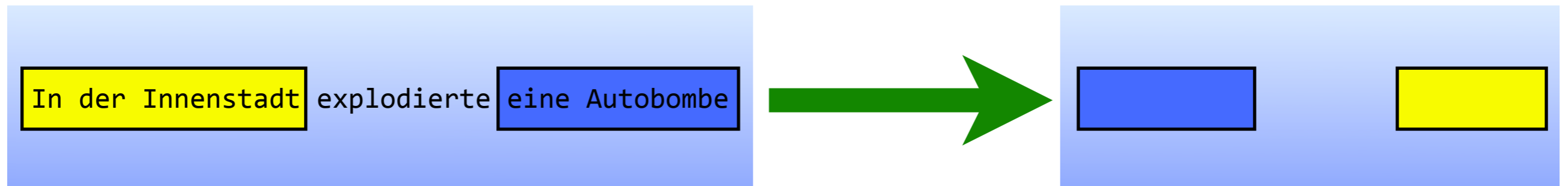
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 - Permute the source words into the target language order

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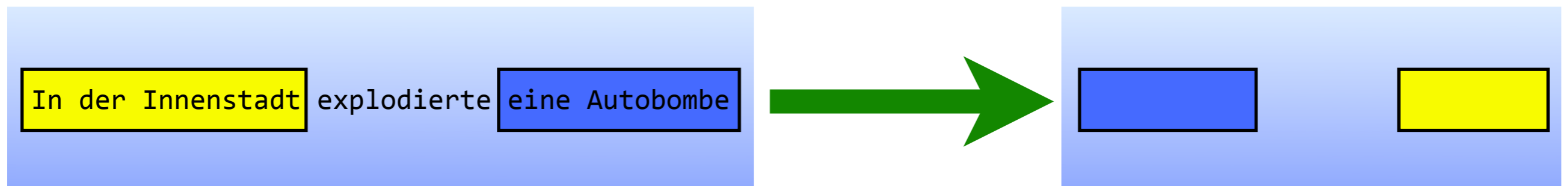
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In der Innenstadt explodierte eine Autobombe

- **Factor problem into (conditionally) independent parts**
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- **Factor problem into (conditionally) independent parts**
 - Permute the source words into the target language order
 - Pick translations for individual words / phrases
 - Probability of particular translations
 - Look at source context
 - Ensure that the output is fluent & idiomatic



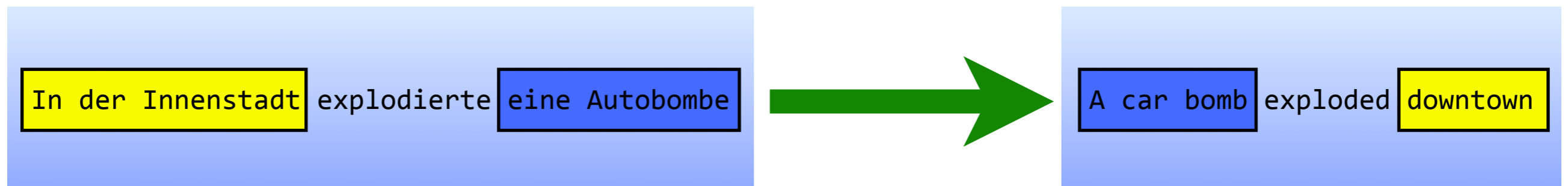
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In der Innenstadt explodierte eine Autobombe



A car bomb exploded downtown

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 - Permute the source words into the target language order
 - Pick translations for individual words / phrases
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 - Ensure that the output is fluent & idiomatic
- **Computational challenges**
 - Searching all word permutations is NP-hard
 - Massive numbers of translation alternatives



- **String-to-string translation**

- Became popular in the 1990's with *statistical MT*
- State-of-the-art for many (most?) language pairs
 - Especially: Closely related language pairs
 - Especially: Typologically similar language pairs
 - ~ Google Translate / Bing Translator
- Limitations
 - Independence assumptions are wrong (too strong *and* too weak)
 - No structural information available to improve modeling
- **Models can be learned directly from *parallel data***

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www.un.org

http://www.un.org/english/

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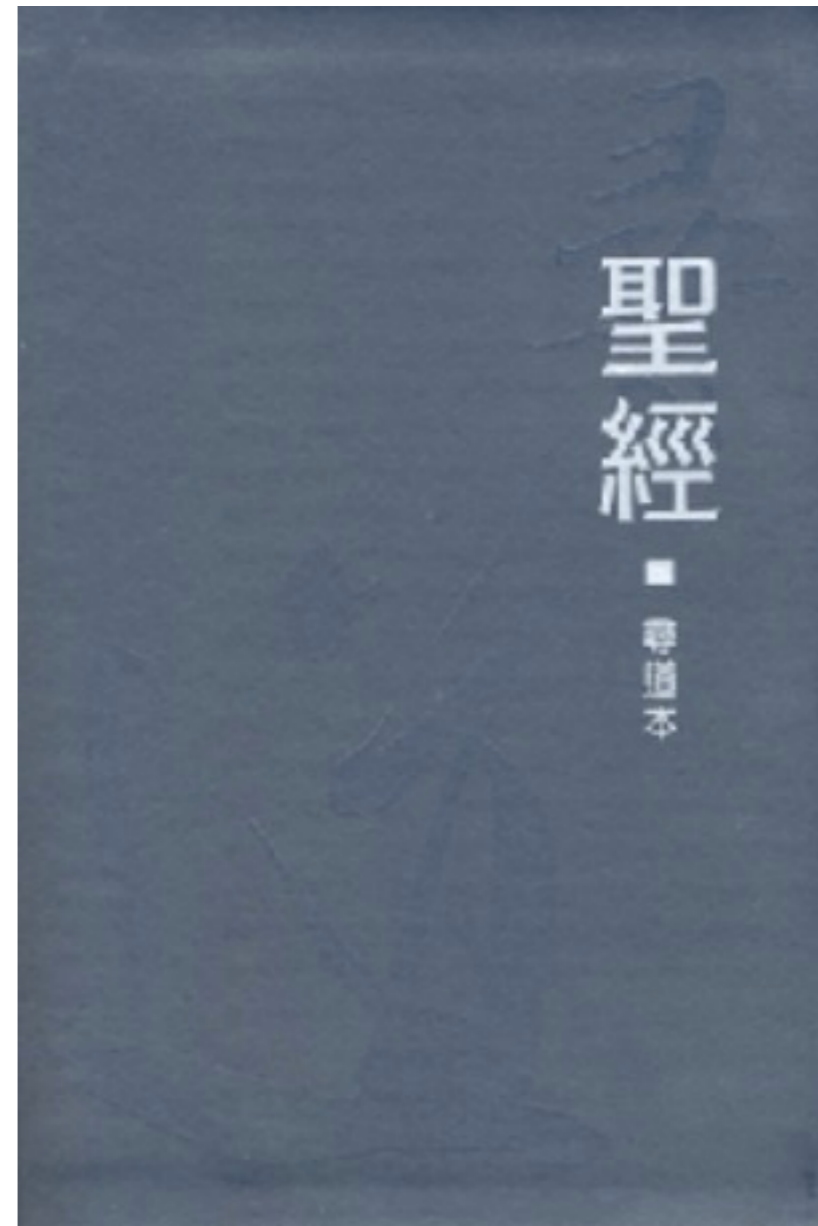
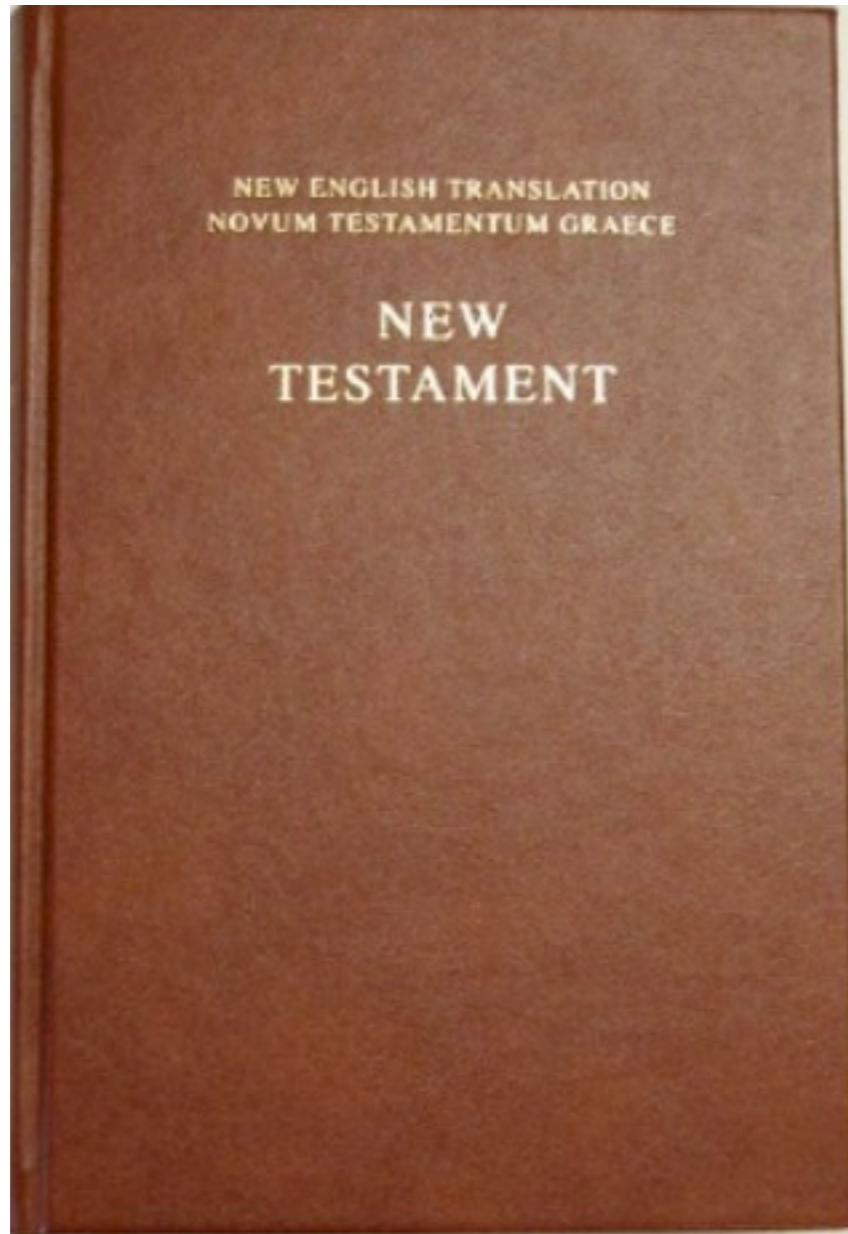
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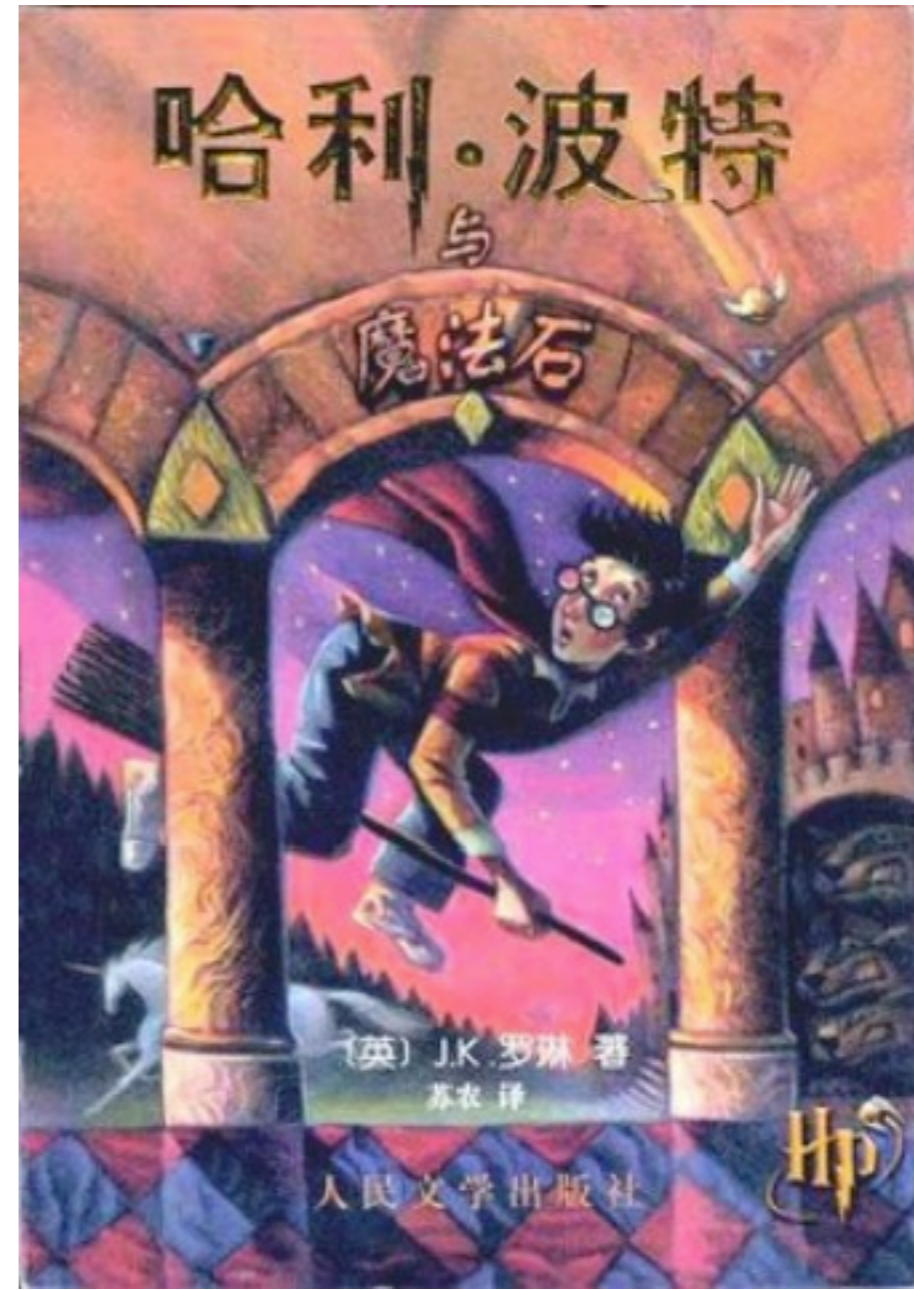
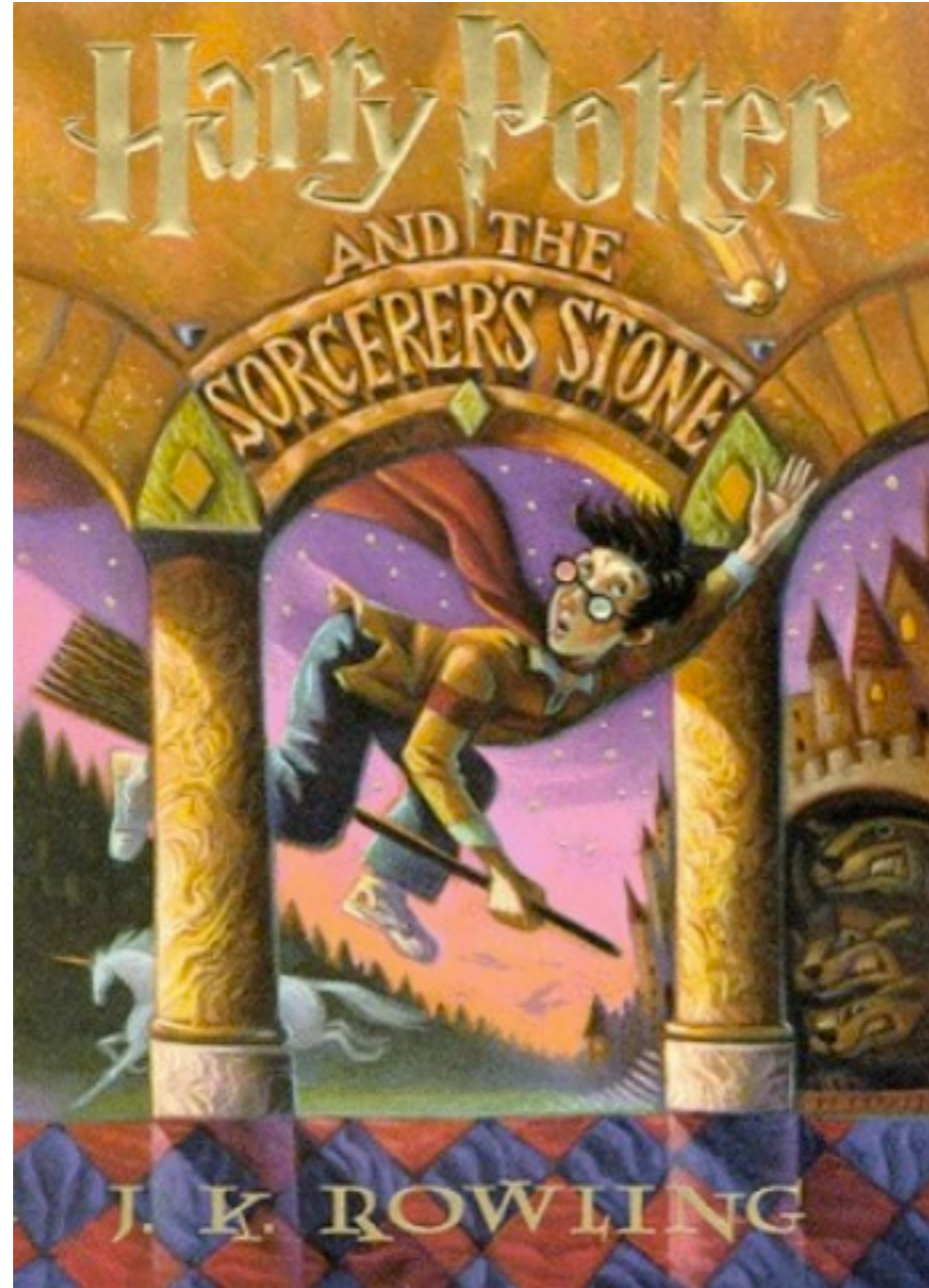
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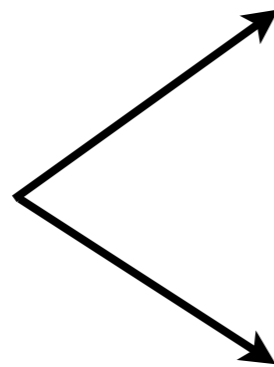




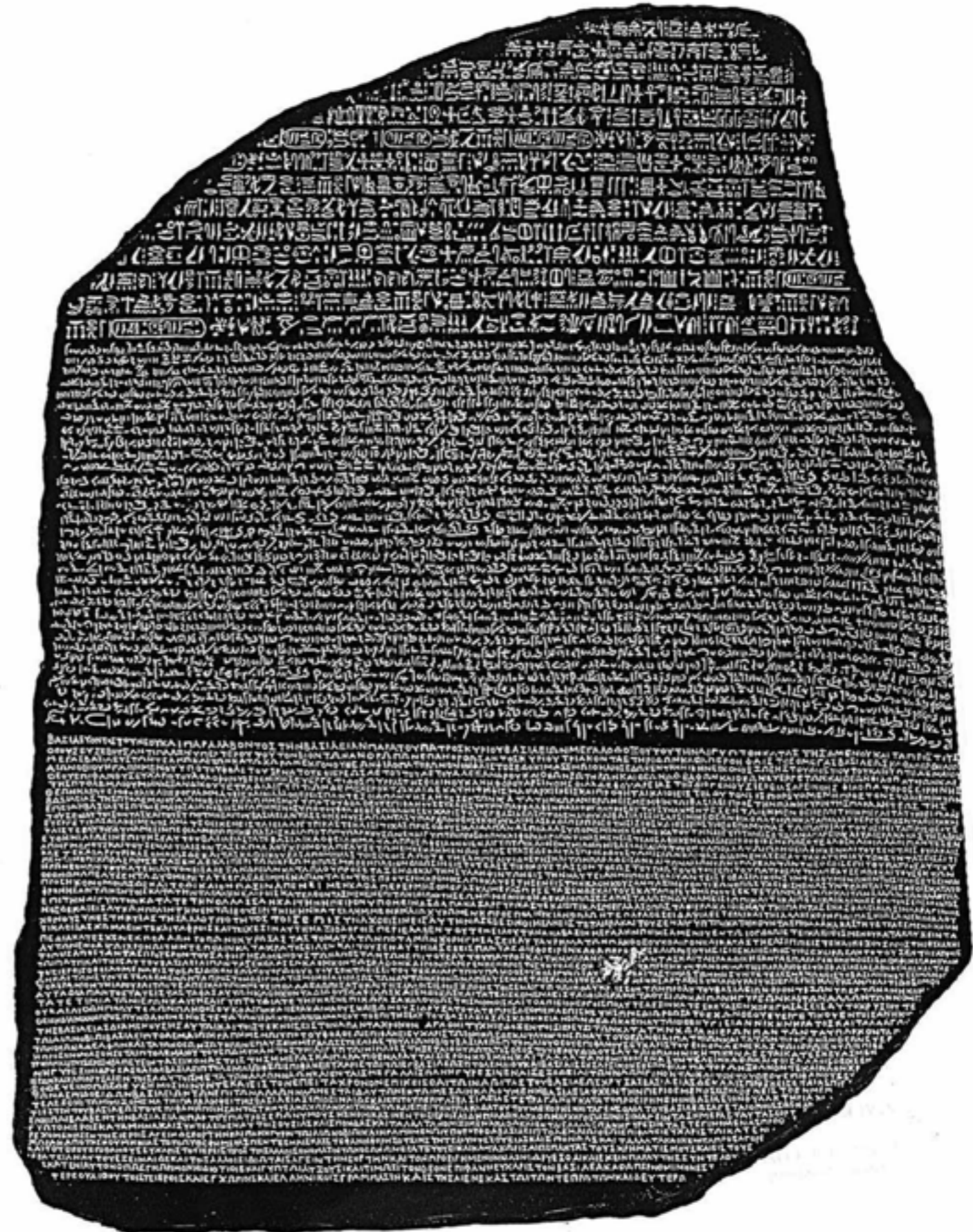
CLASSIC SOUPS

				Sm.	Lg.			
清	燉	雞	湯	57.	House Chicken Soup (Chicken, Celery, Potato, Onion, Carrot)	1.50	2.75	
雞	飯	湯	58.	Chicken Rice Soup	1.85	3.25		
雞	麵	湯	59.	Chicken Noodle Soup	1.85	3.25		
廣	東	雲	吞	60.	Cantonese Wonton Soup.....	1.50	2.75	
蕃	茄	蛋	湯	61.	Tomato Clear Egg Drop Soup	1.65	2.95	
雲	吞	湯	62.	Regular Wonton Soup	1.10	2.10		
酸	辣	湯	63.	Hot & Sour Soup	1.10	2.10		
蛋	花	湯	64.	Egg Drop Soup.....	1.10	2.10		
雲	蛋	湯	65.	Egg Drop Wonton Mix.....	1.10	2.10		
豆	腐	菜	湯	66.	Tofu Vegetable Soup	NA	3.50	
雞	玉	米	湯	67.	Chicken Corn Cream Soup	NA	3.50	
蟹	肉	玉	米	湯	68.	Crab Meat Corn Cream Soup.....	NA	3.50
海	鮮	湯	69.	Seafood Soup.....	NA	3.50		

Egyptian

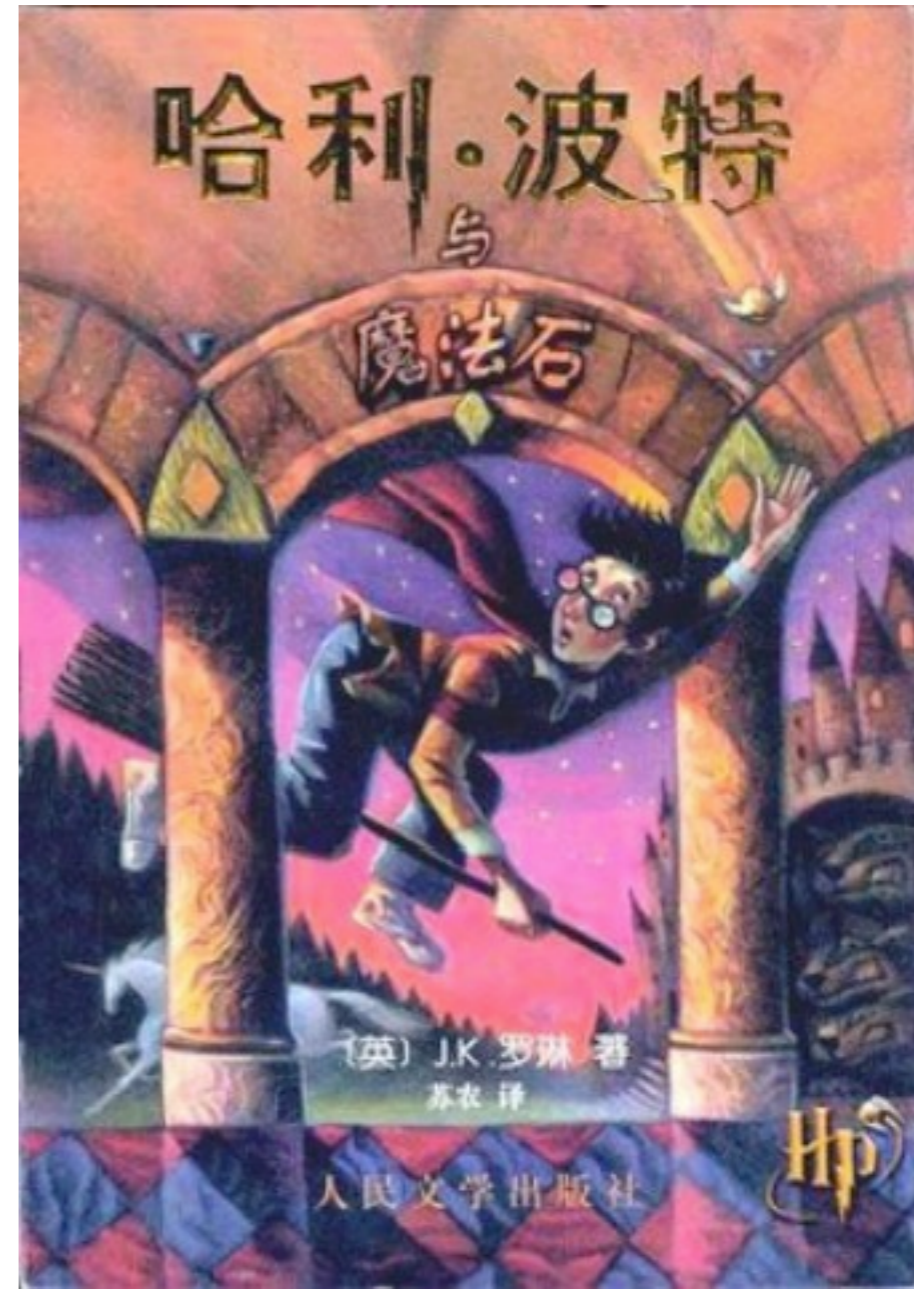
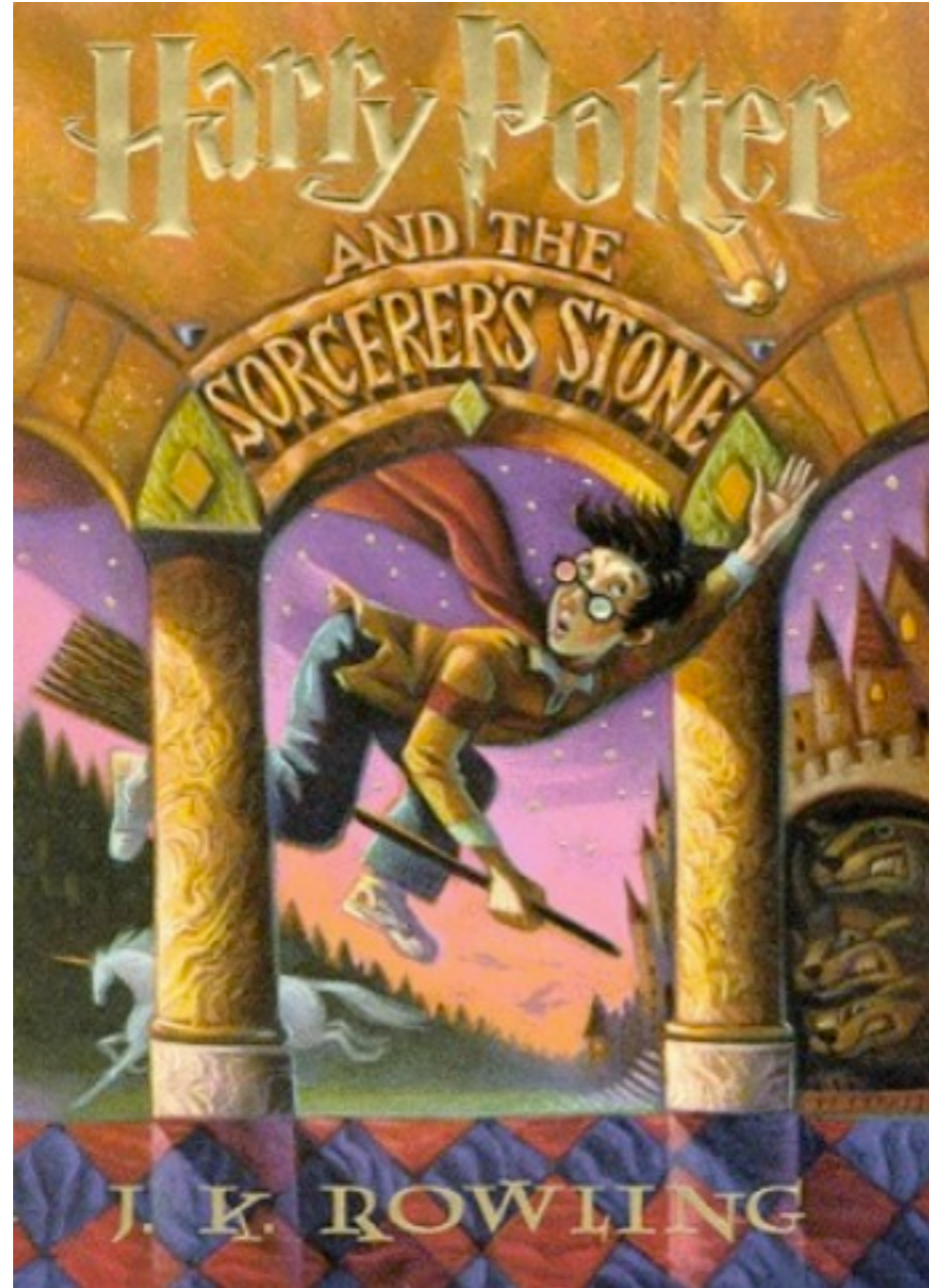


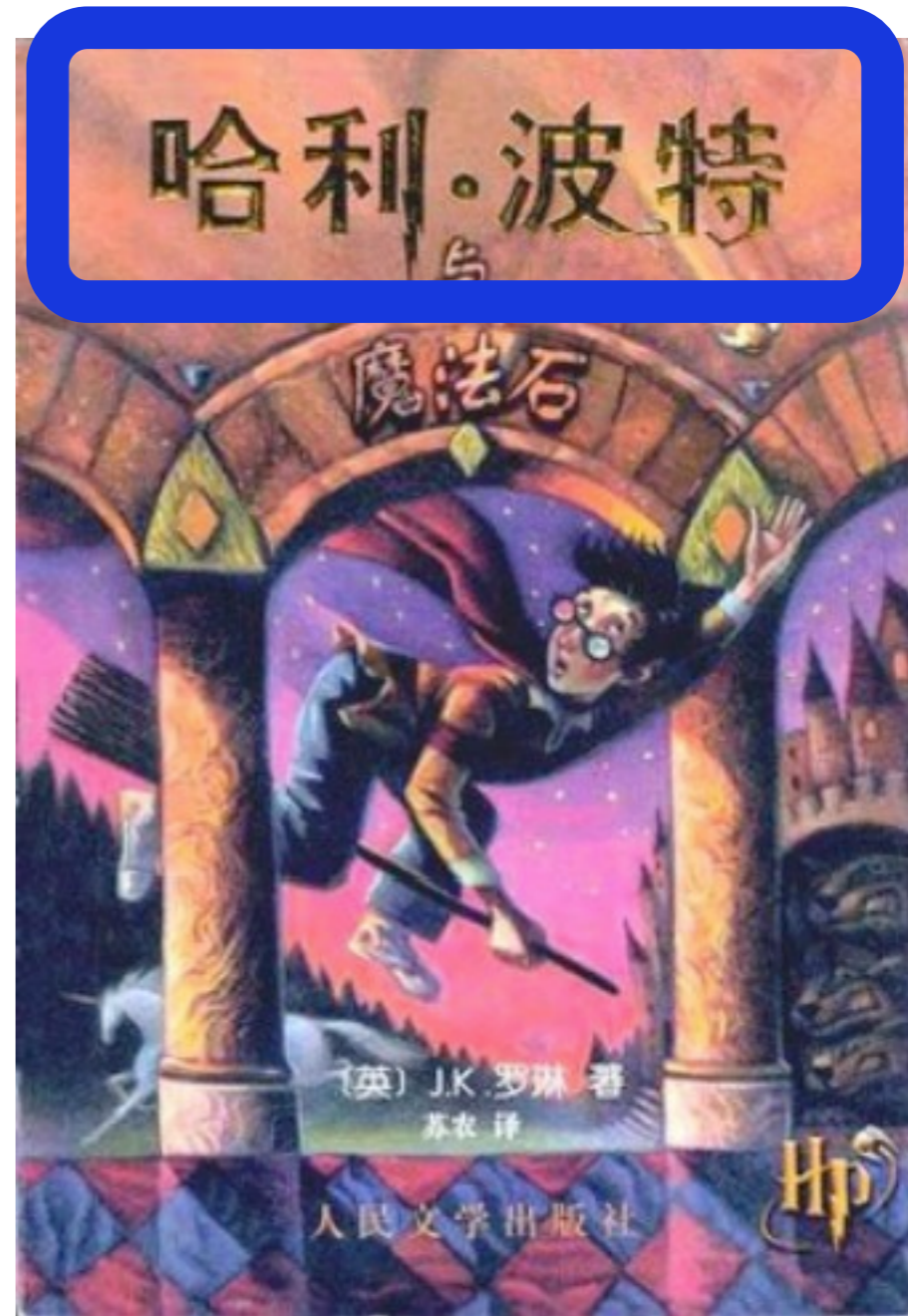
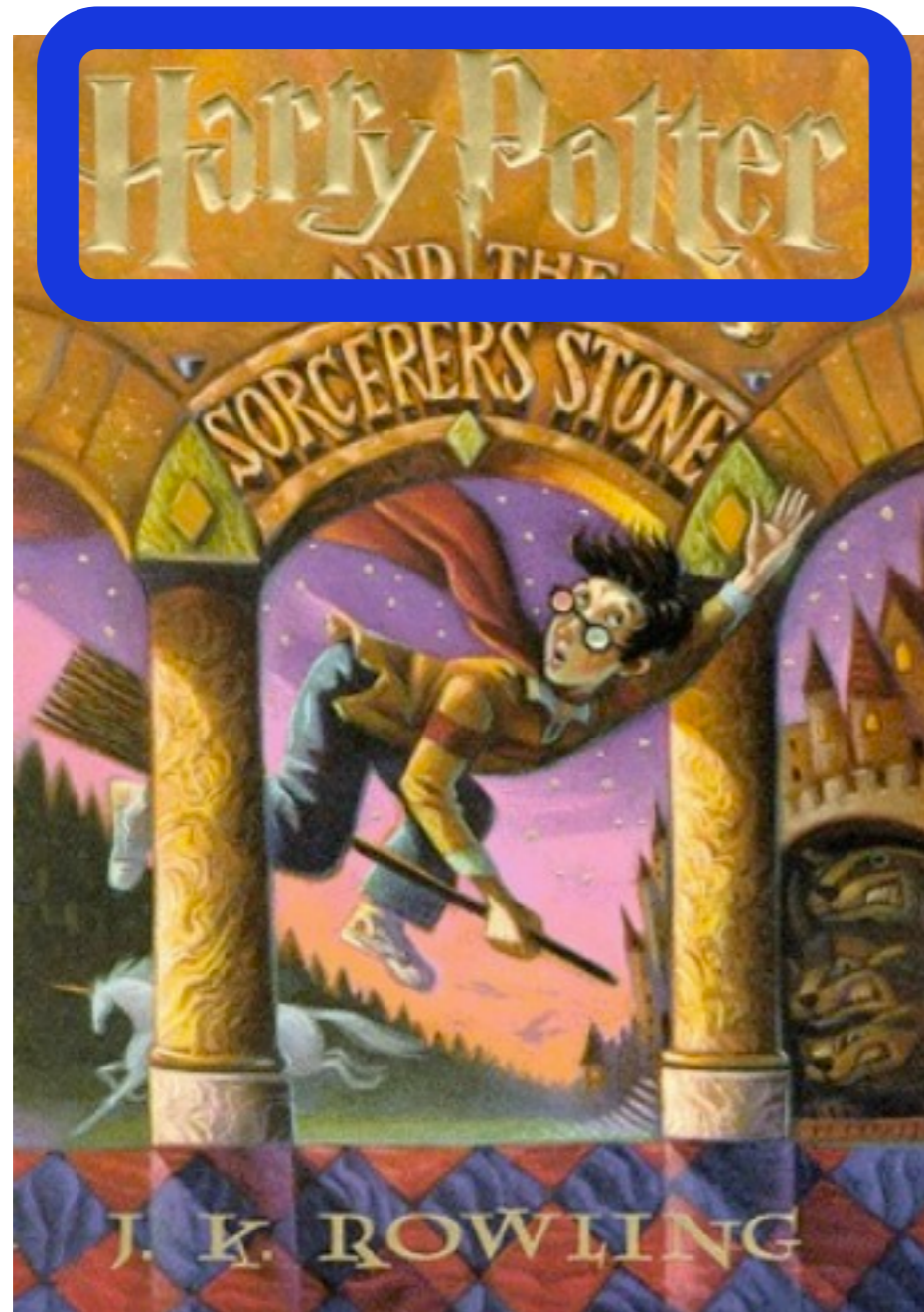
Greek

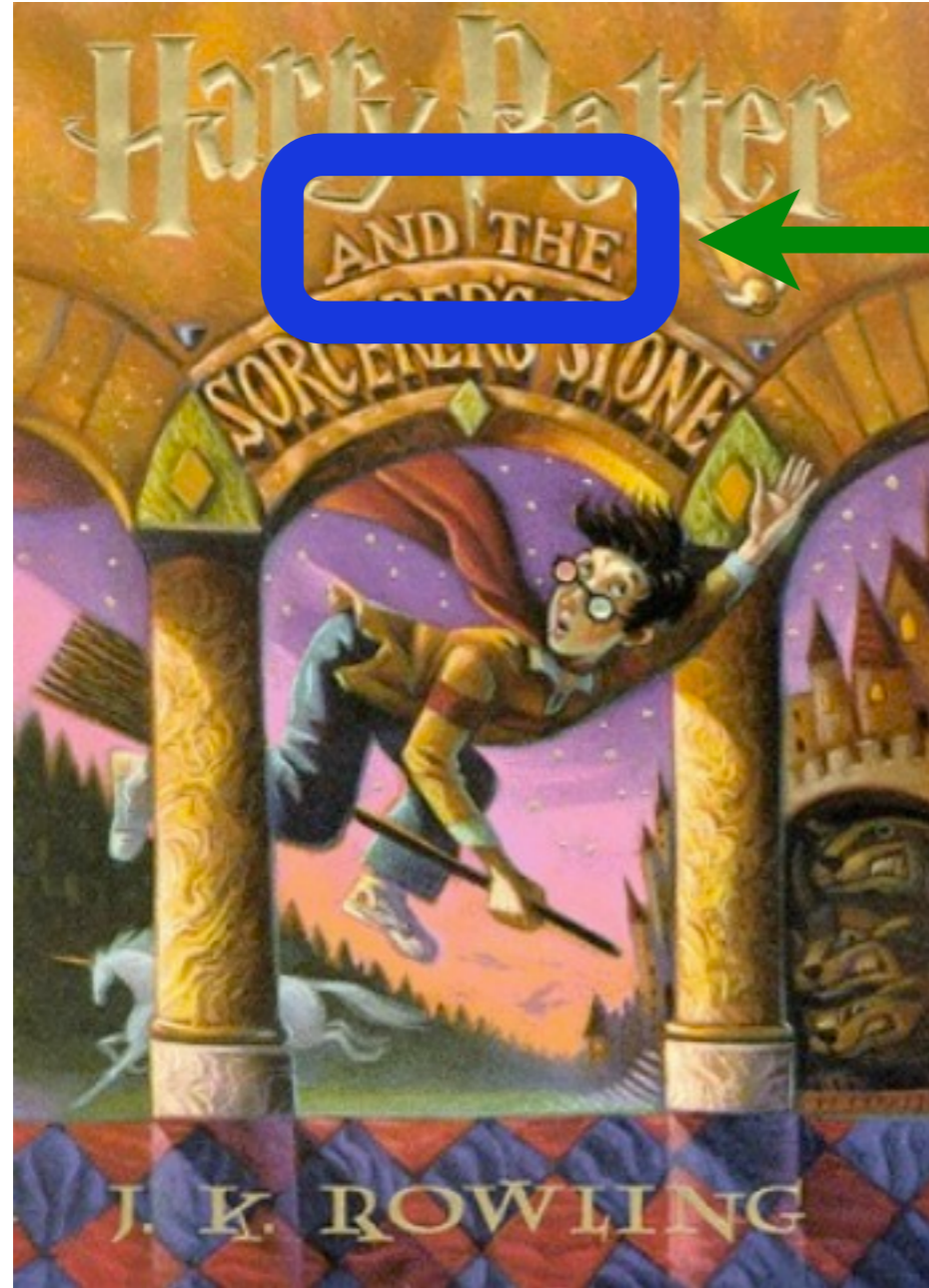


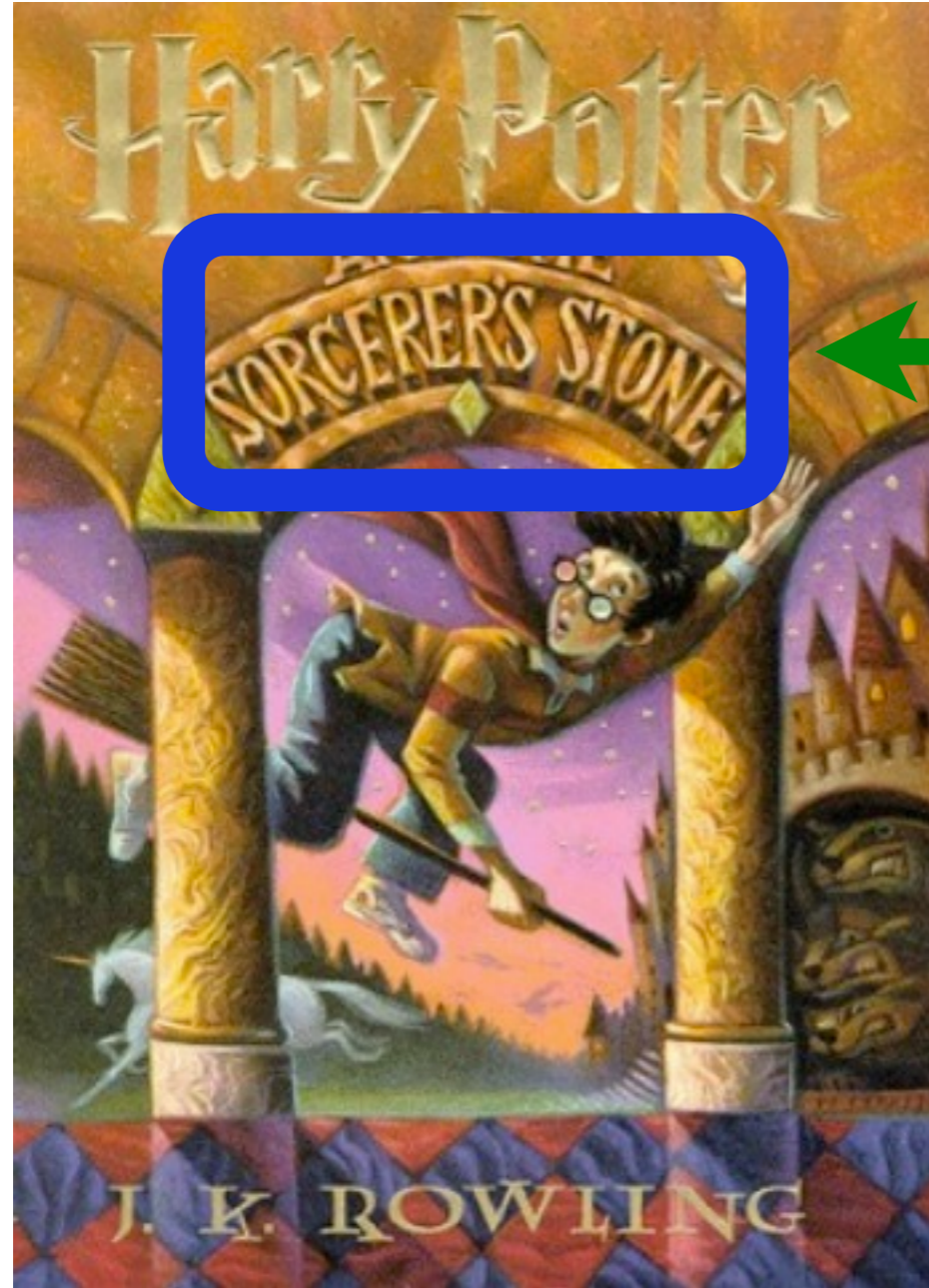
Aside: Parallel Data

- **Alignment**
 - What words / phrases correspond
- **Biingual lexicon induction**
 - Infer possible translations of each word
- **Paraphrase identification**
 - If both **a** and **b** translate as **c**, take this as evidence that **a** and **b** are *synonymous*
- **Distant linguistic supervision**
 - Languages make different things overt (e.g. English has spaces between words, Chinese does not)









CLASSIC SOUPS

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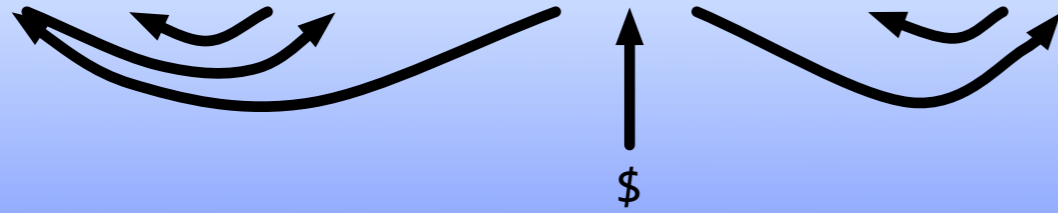
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In der Innenstadt explodierte eine Autobombe



A car bomb exploded downtown

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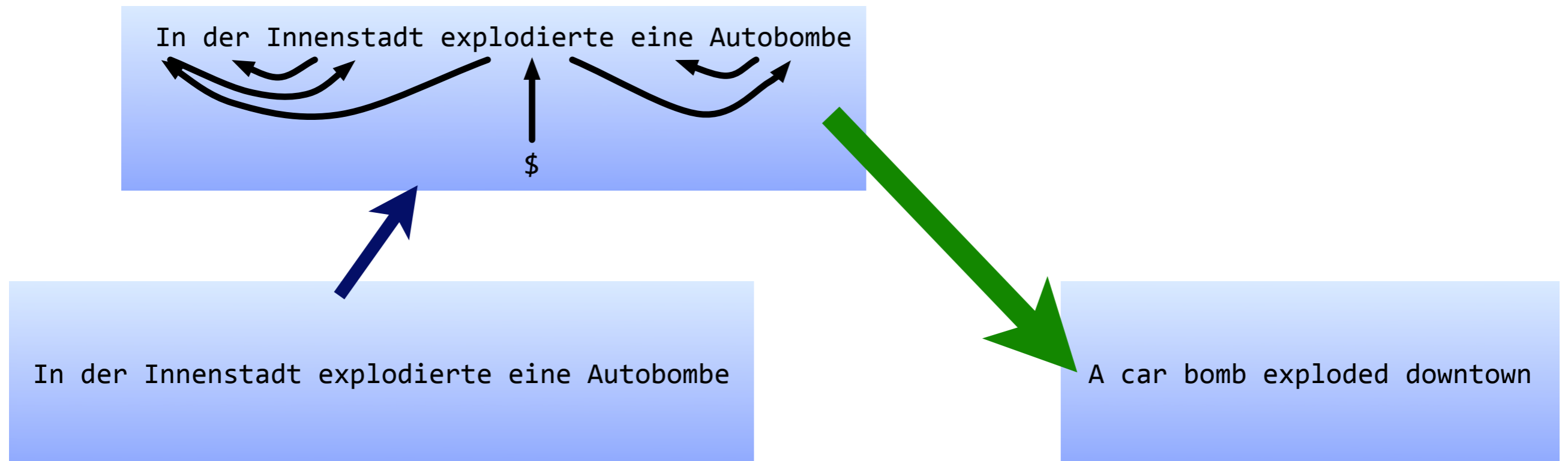
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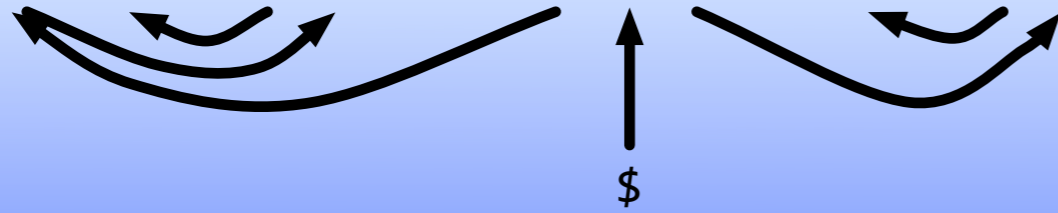
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- **Tree-to-string translation**

- Syntactic *analysis* of source (parse)
- *Transfer* from tree to string
- Source trees have some benefits
 - Proxy for semantic relationships
 - Syntax is a natural source of reordering constraints



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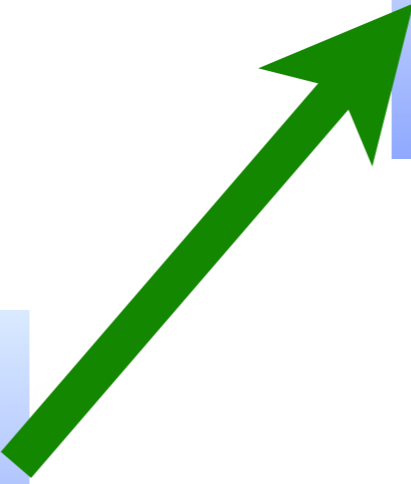


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In der Innenstadt explodierte eine Autobombe



A car bomb exploded downtown

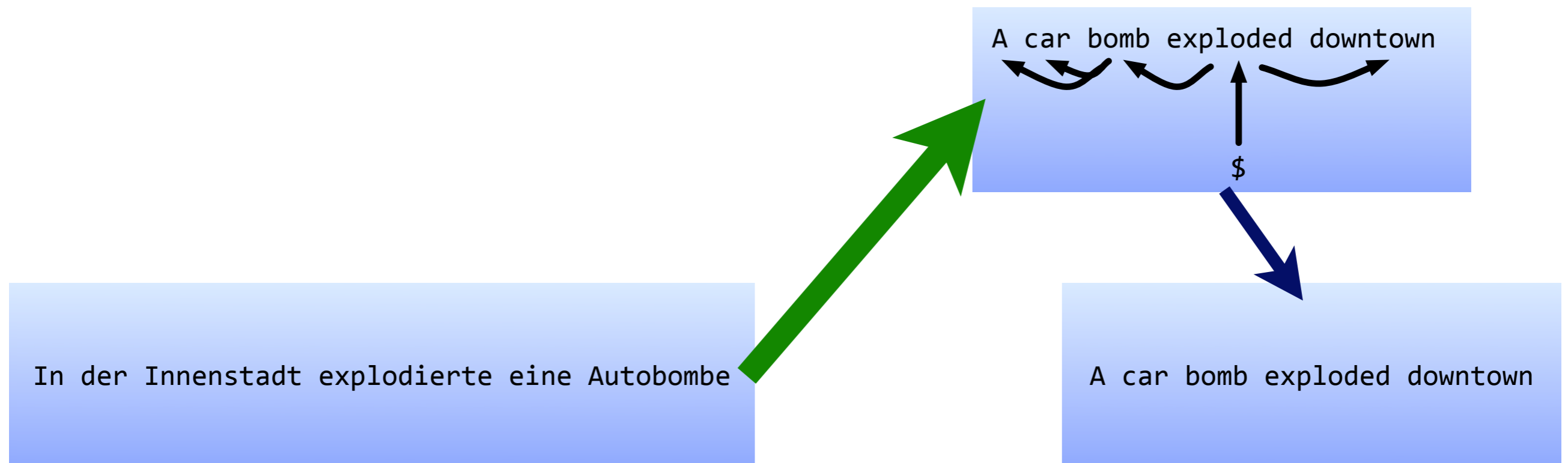
A diagram showing a blue box with the text "A car bomb exploded downtown". Below the text is a dollar sign "\$". A vertical arrow points from the "\$" up to the text. Three curved arrows point from the text to the left, right, and down.

A car bomb exploded downtown



- **String-to-tree translation**

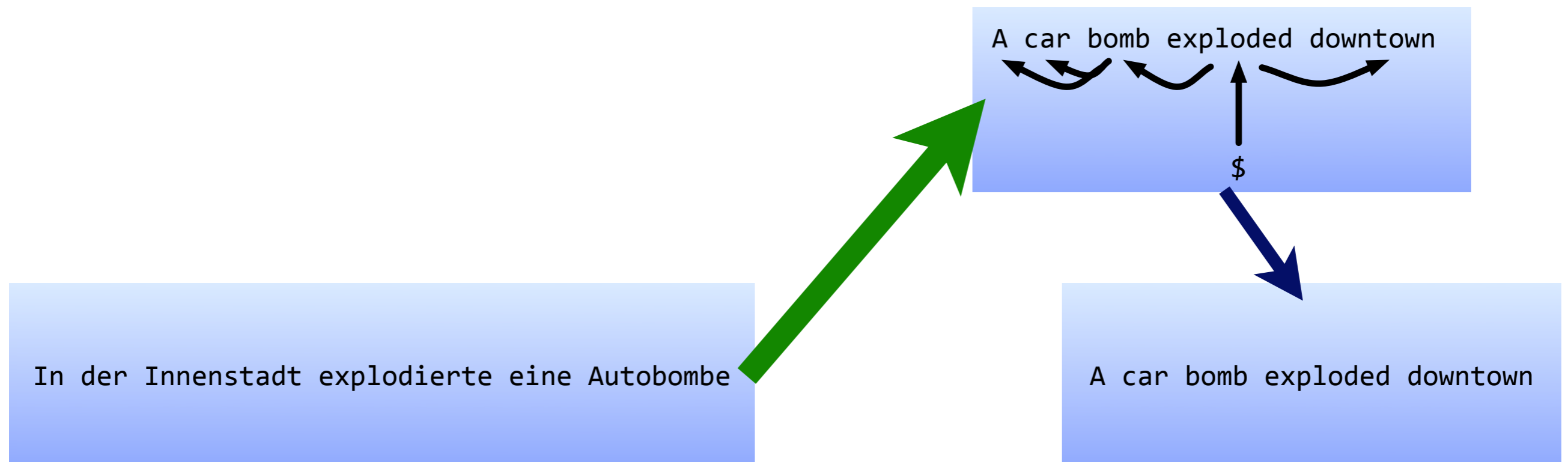
- Transfer from source tree to target string
- Formally a generalization of **monolingual parsing**
- Intuition: it is more important to know the language you are translating into well than the source language



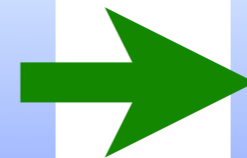
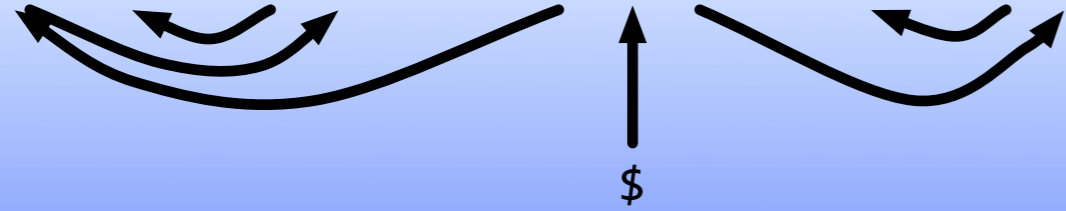
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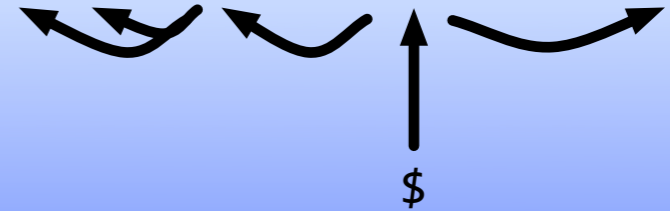
The best Chinese-English systems are string-to-tree



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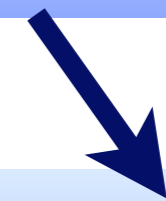
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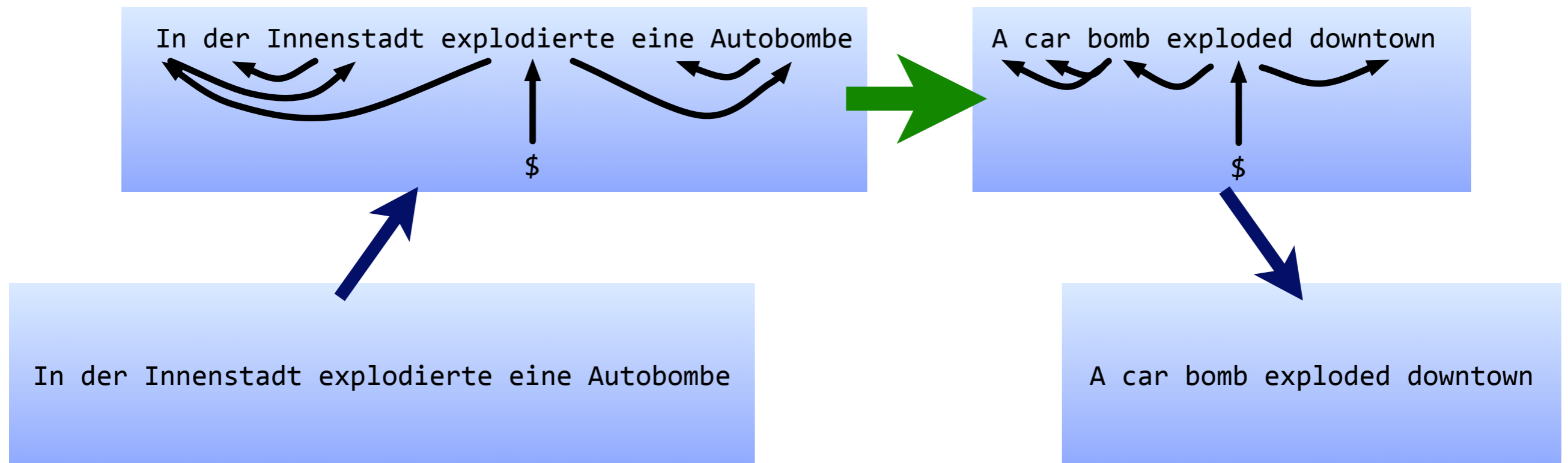


A car bomb exploded downtown



- **Tree to tree translation**

- Use syntax to predict syntax
- Benefits
 - As parsers improve, MT will improve (we hope)
 - Rich information for modeling in source and target
- Downside: where does the syntax come from?



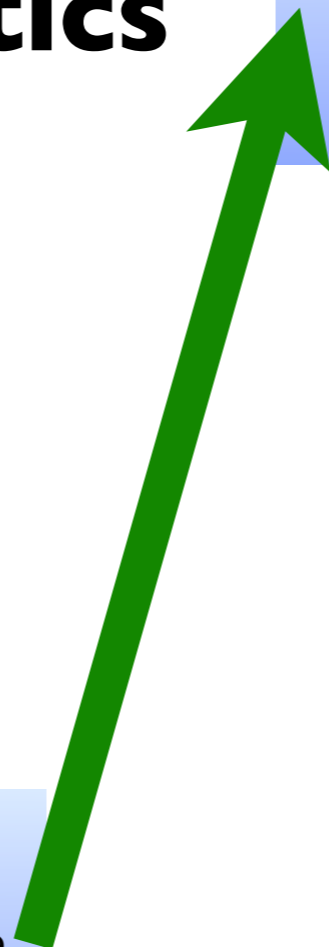
In der Innenstadt explodierte eine Autobombe

Semantics

“logical form”

detonate
:arg0 bomb
:arg1 car
:loc downtown
:time past

In der Innenstadt explodierte eine Autobombe



Semantics
“logical form”

Syntax

```
detonate  
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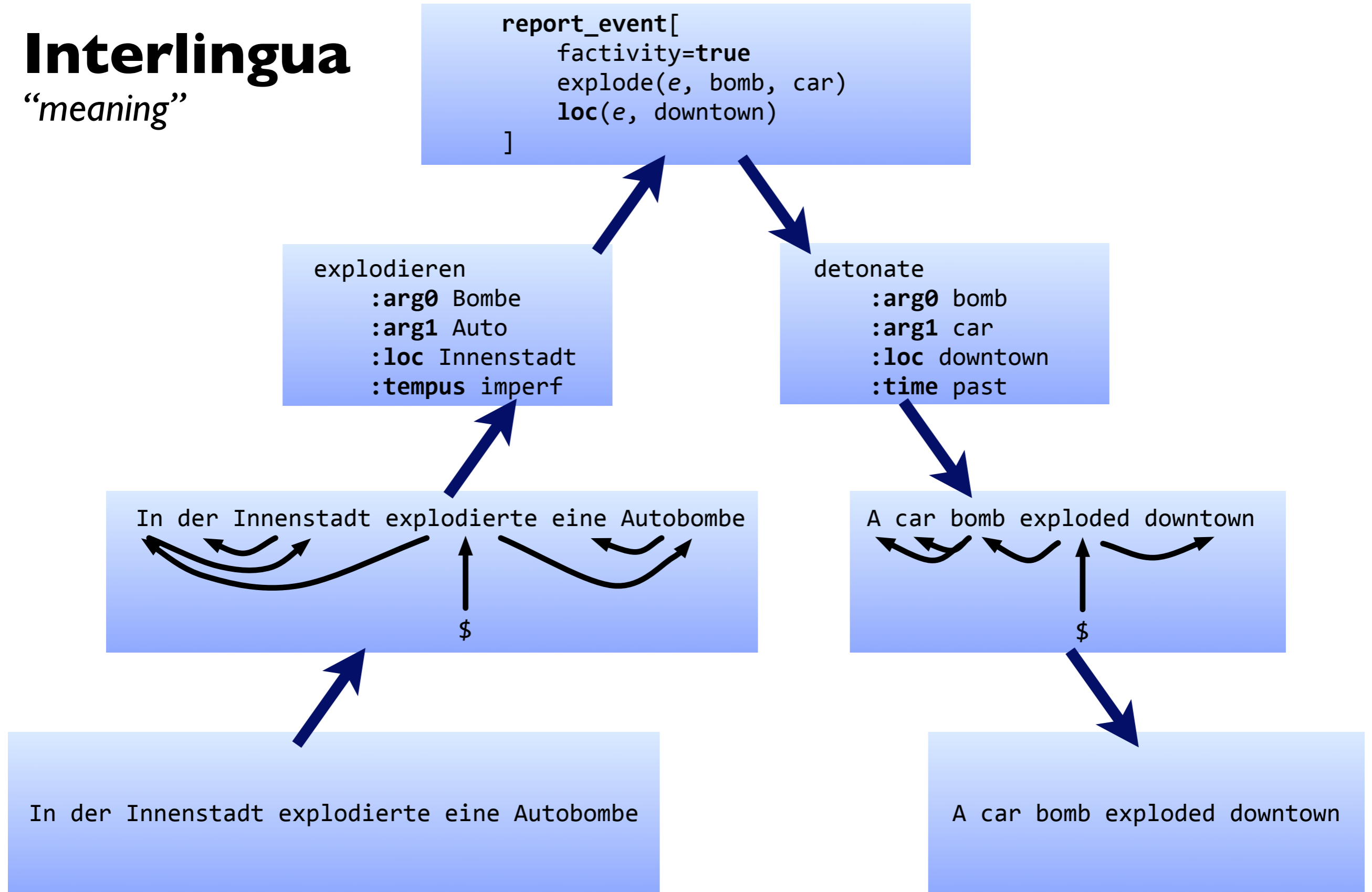
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Interlingua

“meaning”



More Abstract Models

More Abstract Models

- **Modeling challenges**
 - What are the right abstract representations?
 - How do we support more abstraction without sacrificing accuracy on frequent elements?

More Abstract Models

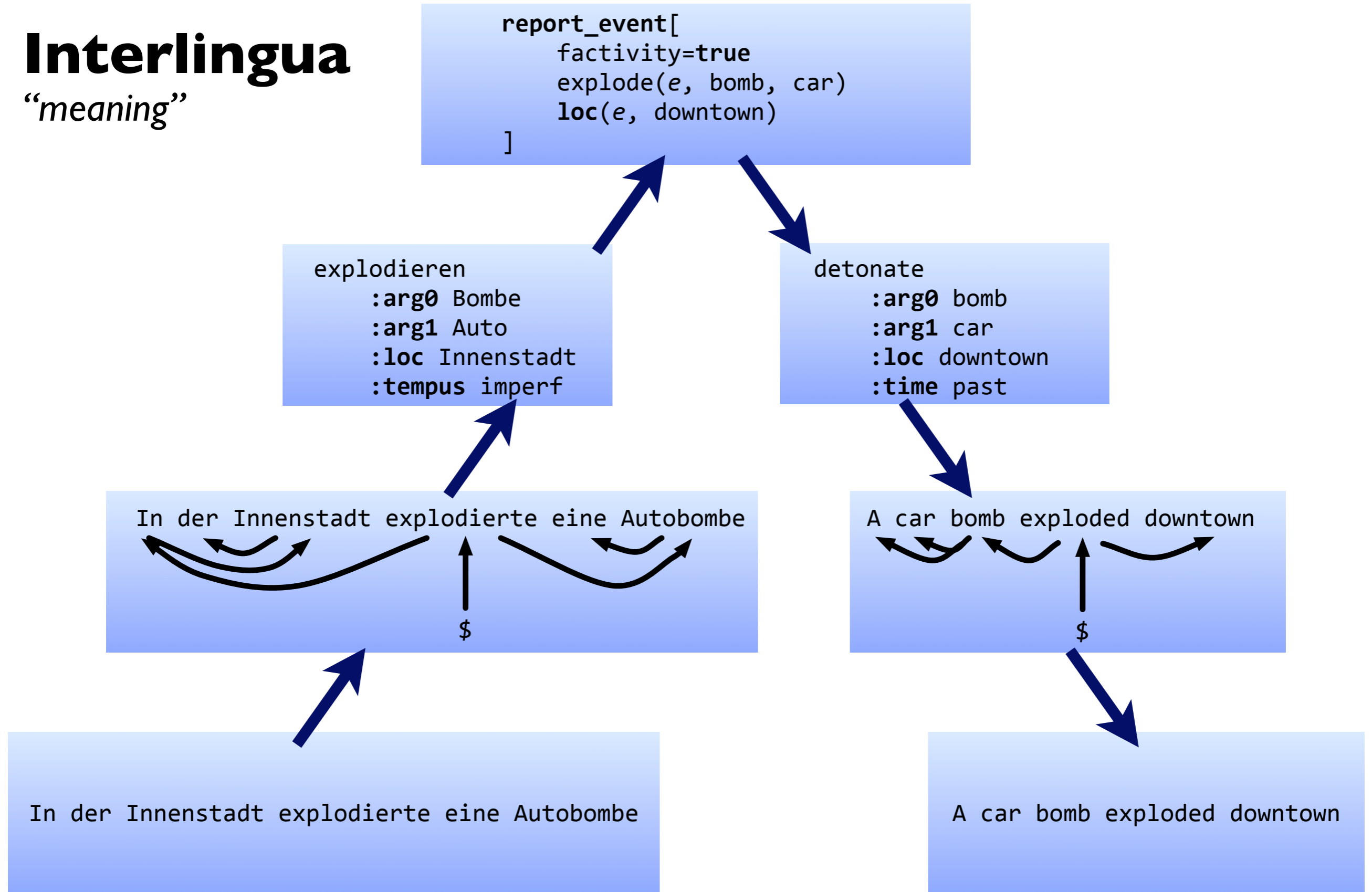
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 - Large search spaces
 - Error propagation in pipelines

More Abstract Models

- **Modeling challenges**
 - What are the right abstract representations?
 - How do we support more abstraction without sacrificing accuracy on frequent elements?
- **Computational challenges**
 - Large search spaces
 - Error propagation in pipelines
- **Learning challenges**
 - Nonconvexity
 - Where does the data come from?

Interlingua

“meaning”



Interlingua

“meaning”

```
report_event[  
  factivity=true  
  explode(e, bomb, car)  
  loc(e, downtown)  
]
```

Hidden

```
explodieren  
:arg0 Bombe  
:loc Innenstadt  
:tempus Imperf
```

```
detonate  
:arg0 bomb  
:arg1 car  
:loc downtown  
:time past
```

In der Innenstadt explodierte eine Autobombe

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Other Challenges

European parliament language (training):

I declare resumed the session of the European Parliament adjourned on Friday 17 December 1999, and I would like once again to wish you a happy new year in the hope that you enjoyed a pleasant festive period.

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Human language (testing):



Its Me Edith :) @Lovelyyedi

40m

Birthday is on sunday & im pribably not doin anythin cause mom planned that other thing for sat nd sunday idk tf ima do -.-

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spelling error

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abbreviations

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nonstandard contractions

Using Translation



This page is in

Chinese ...

Would you like to translate it?

Nope

Translate

解读31位省级党委书记 下过乡扛过枪当过知青

[31位省级党委“一把手”平均年龄不到60岁] [网友：全国31个省级党委换届一把手突出“三个特点”]



老党员重温入党誓词

党建纵览

党建周刊

网站联盟

- 干部“贿赂群众”说明了啥|女博士生咋患“..."
- 政务微博超45000个“电视问政”问出...
- 山东东营“的哥的姐”有了党支部|万余群众...
- 上海有个每周日跑菜场的党支部 | 杭州拱墅区...
- 辽宁抚顺：四千余名中小學生成为“娃娃楼长”...

- 全国31个省区市中省委常委任统战部长达23人
- 人民论坛：干部有危机感，群众才有幸福感
- 浙江湖州市一镇党委副书记阻挠采访被撤职

- 莒县县委书记刘守亮：脚上不沾泥很难说是好干部
- 四川宜宾市翠屏区：天都黑了 还能见到干部夜访...
- 广西百色构建乡镇书记“阳光上升通道”观察
- 聚焦来自基层一线的军队十八大代表 >>寄语留言
- 广东佛冈县率先在全省推行县直单位一把手挂任村...
- 深圳市南山区“书记信箱”开通500期 成为反...
- 记四川乐山市金口河区共安彝族乡林丰村党支部
- 江西黎川设党政班子集中办事大厅 12名乡镇领...
- 浙江省桐乡市石门镇暨丰村：80后村支书治村有...

- “联盟成员单位优秀稿件采用排行榜” (5月)
- 专题：走进基层党支部 | 历史文献纪录片《信仰》

解读31位省级党委书记 下过乡扛过枪当过知青

[31 provincial party committee "in charge" an average age of less than 60 years old] [users: the country's 31 provincial party committee leaders to highlight the "three characteristics"]



老党员重温入党誓词

Party Building Party Building Affiliate
Overview Week

- The cadres "bribe the masses," the Han | the female doctoral ye suffering from ...
- government microblogging over 45 000 | TV politics
- "asked a ...
- Shandong Dongying "the brother of the sisters have a party branch | thousand masses ...
- Shanghai party branch every Sunday ran farms |

- any of the United Front Work Department of the Provincial Standing Committee in the country's 31 provinces, autonomous regions and municipalities for up to 23 people, the People's Forum: cadres have a sense of crisis, the masses have the happiness
- Zhejiang Huzhou City, a town of the party deputy secretary obstruct interview is dismissed

- Juxian county party secretary Liu Shouliang: non-stick feet mud is hard to say the good cadres
- Sichuan Yibin City Cuiping: days are dark can see the cadres Interview ... the Guangxi Baise build township secretary sun rising channel observation
- focus from the front line of the grass-roots army 48 Congress >> Message Message
- Guangdong Fogang the first in the province implement

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lays a do not stick see the
"the s non - stick tunnel" to
s-roots nonstick congress
roduce does not stick vince co
zhen district, "t
on Leshan Sichuan Provi

HCI question for MT

- Statistical MT systems know **way more** about translation than any human can know
- Yet we end up with ***non-stick mud***
- **How can we help people find the information they need?**

Non-Written Languages

- **There's a bigger world than text**
 - *Spoken* language
 - *Written* language (text from images)
 - *Signed* language
- **Research questions**
 - How do we translate to languages with no (standard) orthography?
 - Non-standard dialects
 - Minority languages
 - Signed language
 - ...Twitter & Email
 - How do we deal with recognition errors?
 - How should humans use speech-to-speech translation devices?



Evaluation



More has been written about machine translation evaluation than about machine translation itself.

- Yorrick Wilks

The gold standard?

- Human evaluation
 - Have annotators read and assess translations
 - (Fluency, adequacy)
 - Have annotators read translations and do something



Is the cake delicious?



Human evaluation

- Problems
 - Humans don't like to evaluate translation, especially bad translation
 - Humans don't tend to agree with each other

A: furious nAgA on wednesday , the tribal minimum pur of ten schools also was burnt .

B: furious nAgA on wednesday the tribal pur mini ten schools of them was also burnt .

Automatic Evaluation

Automatic Evaluation

- Evaluating translation automatically is **hard**
 - There are many correct ways to say something
 - If we could measure if a sentence was grammatical and a good translation, then we would have solved the translation problem!

Automatic Evaluation

- Evaluating translation automatically is **hard**
 - There are many correct ways to say something
 - If we could measure if a sentence was grammatical and a good translation, then we would have solved the translation problem!
- But...
 - Computers are cheap and reliable
 - Computers don't mind evaluating (bad) translation output
 - During the translation process, systems must evaluate massive search spaces, but evaluation usually just looks at a few hypotheses
 - Our “bad” metrics have led to vastly improved translation quality!
 - If we had a great automatic metric, we could make things even better

In Conclusion

Machine Translation

- Algorithms & automata theory
- Human-computer interaction
- Linguistics
- Machine learning and statistics
- Many NLP technologies
 - Morphology
 - Syntax
 - Semantics
 - Discourse
- System engineering

Questions?