## Translation Options

<table>
<thead>
<tr>
<th>Maria</th>
<th>no</th>
<th>dio</th>
<th>una</th>
<th>bofetada</th>
<th>a</th>
<th>la</th>
<th>bruja</th>
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- Look up possible phrase translations
  - many different ways to segment words into phrases
  - many different ways to translate each phrase
Hypothesis Expansion

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- Start with empty hypothesis
  - e: no English words
  - f: no foreign words covered
  - p: probability 1
Hypothesis Expansion

- Pick translation option
- Create hypothesis
  - e: add English phrase Mary
  - f: first foreign word covered
  - p: probability 0.534
## Hypothesis Expansion

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**Add another hypothesis**

- e: witch
  - f: 
  - p: .18
- e: Mary
  - f: 
  - p: .534
Hypothesis Expansion

- Further hypothesis expansion
Hypothesis Expansion

- Maria
- no
- dio una bofetada
- a la
- bruja verde

... until all foreign words covered
- find best hypothesis that covers all foreign words
- backtrack to read off translation
Hypothesis Expansion

- Adding more hypothesis

⇒ Explosion of search space
Explosion of Search Space

- Number of hypotheses is exponential with respect to sentence length

⇒ Decoding is NP-complete [Knight, 1999]
⇒ Need to reduce search space
  - risk free: hypothesis recombination
  - risky: histogram/threshold pruning
Hypothesis Recombination

- Different paths to the same partial translation
Hypothesis Recombination

- Different paths to the same partial translation

⇒ Combine paths
  - drop weaker hypothesis
  - keep pointer from worse path
Hypothesis Recombination

- Recombined hypotheses do not have to match completely
- No matter what is added, weaker path can be dropped, if:
  - last two English words match (matters for language model)
  - foreign word coverage vectors match (effects future path)
Hypothesis Recombination

- Recombined hypotheses do not have to match completely
- No matter what is added, weaker path can be dropped, if:
  - last two English words match (matters for language model)
  - foreign word coverage vectors match (effects future path)

⇒ Combine paths
Pruning

- Hypothesis recombination is not sufficient

⇒ Heuristically discard weak hypotheses

- Organize Hypothesis in stacks, e.g. by
  - same foreign words covered
  - same number of foreign words covered (Pharaoh does this)
  - same number of English words produced

- Compare hypotheses in stacks, discard bad ones
  - histogram pruning: keep top $n$ hypotheses in each stack (e.g., $n=100$)
  - threshold pruning: keep hypotheses that are at most $\alpha$ times the cost of best hypothesis in stack (e.g., $\alpha = 0.001$)