Overview

- Latent semantic analysis
  - words as vectors
- Neural networks
  - distributed representation
  - spreading activation
  - adjustment of connection strengths
- Simple Recurrent Networks
  - recurrence
  - emergent representation
- learning
  - back propagation (next week)

what is meaning?

- the meaning of a word is knowledge of the contexts in which that word can occur.
- words with similar meanings can be used in similar contexts
- *similarity* and *context* are good ways to think about the mental representation of meaning
  - The more similar the meanings, the more their representations 'overlap' (= "semantic overlap")

co-occurrence

- On average, the words in a description of the *brain* are more similar to each other than to words in a description of a *drain*.
  - *The brain is an organ that serves as the center of the nervous system in all vertebrate and most invertebrate animals.*
  - *In some systems the drain is for discharge of waste fluids, such as the drain in a sink in which the water is drained when it is no longer needed.*
- words that co-occur in such descriptions are more similar to one another than to words that do not
  - the premise underlying *Latent Semantic Analysis*

Landauer & Dumais, 1997: LSA

(60,768 words, 30,473 articles)

- An example:

	Context (Document)				
	#1	#2	#3	#4	#5
CAT					
DOPAMINE					
DOG					
REWARD					

- CAT and DOG are more similar to each other than they are to DOPAMINE or REWARD.
- Conversely, DOPAMINE and REWARD are more similar to each other than they are to CAT or DOG.
- There is some overlap between DOG and REWARD

Landauer & Dumais, 1997: LSA
(60,768 words, 30,473 articles)

- An example:

Context (Document)				
	#1	#2	#3	coordinate
CAT	✔			
DOPAMINE			✔	
DOG	✔	✔		
REWARD		✔	✔	

Landauer & Dumais, 1997: LSA

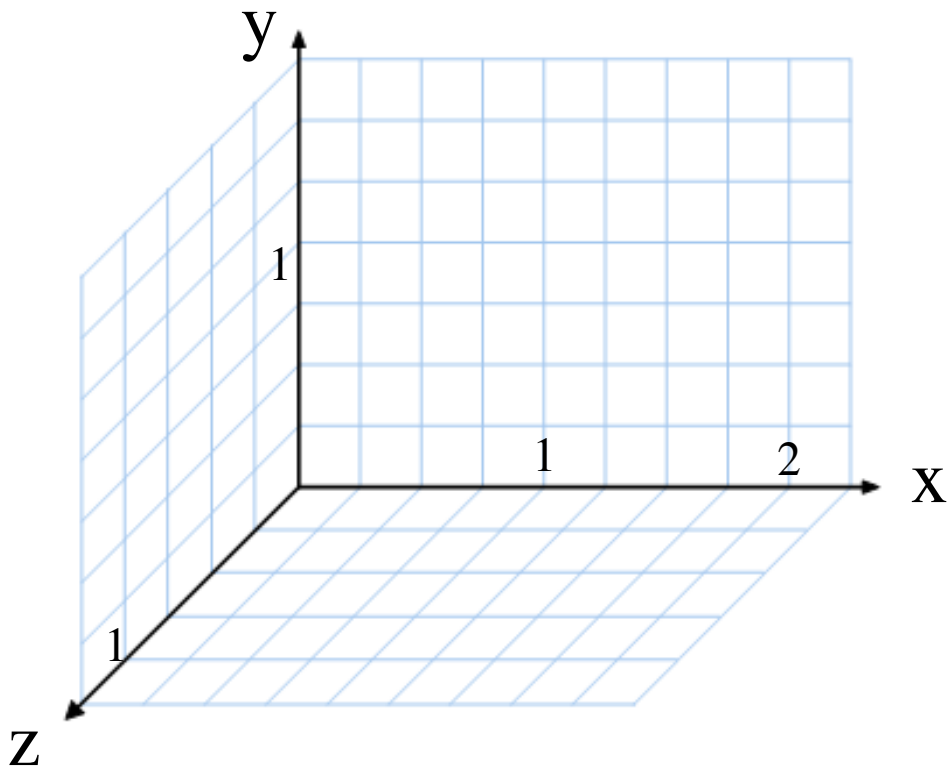
(60,768 words, 30,473 articles)

- An example:

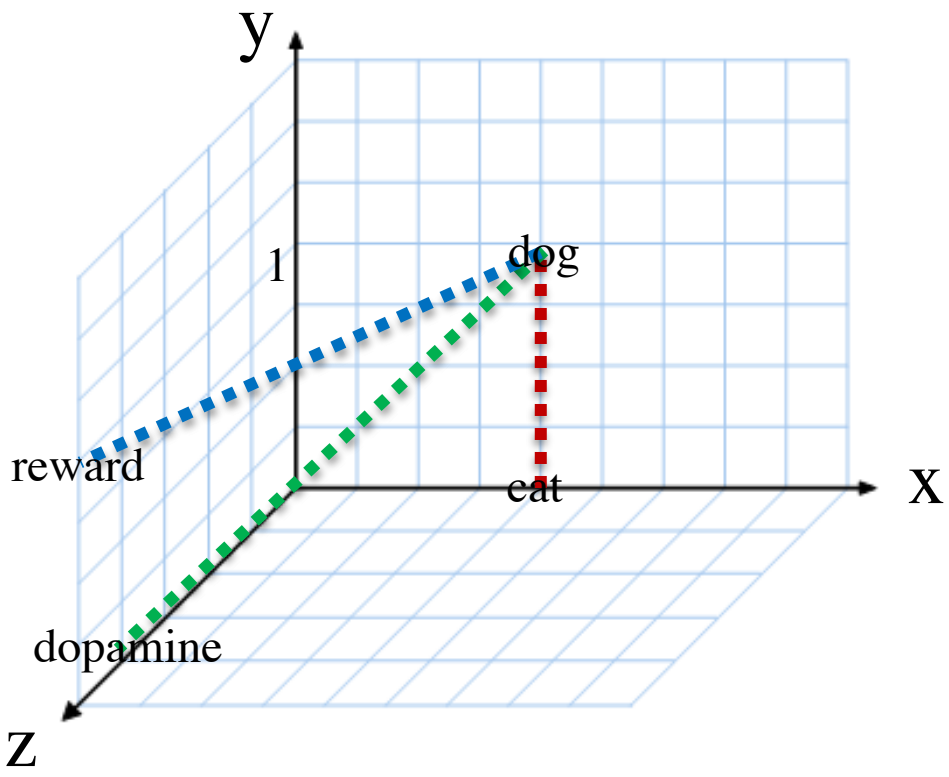
Context (Document)				
	#1	#2	#3	coordinate
CAT	✔			1, 0, 0
DOPAMINE			✔	0, 0, 1
DOG	✔	✔		1, 1, 0
REWARD		✔	✔	0, 1, 1

Context (Document)				
	#1	#2	#3	coordinate
CAT	✔			1, 0, 0
DOPAMINE			✔	0, 0, 1
DOG	✔	✔		1, 1, 0
REWARD		✔	✔	0, 1, 1

Context (Document)				
	#1	#2	#3	coordinate
CAT	✔			1, 0, 0
DOPAMINE			✔	0, 0, 1
DOG	✔	✔		1, 1, 0
REWARD		✔	✔	0, 1, 1



Context (Document)				
	#1	#2	#3	coordinate
CAT	✔			1, 0, 0
DOPAMINE			✔	0, 0, 1
DOG	✔	✔		1, 1, 0
REWARD		✔	✔	0, 1, 1



Landauer & Dumais, 1997: LSA

(60,768 words, 30,473 articles)

- count how many times each word occurs in each 'document'
- reduce the dimensions through a form of factor analysis (principle components analysis)

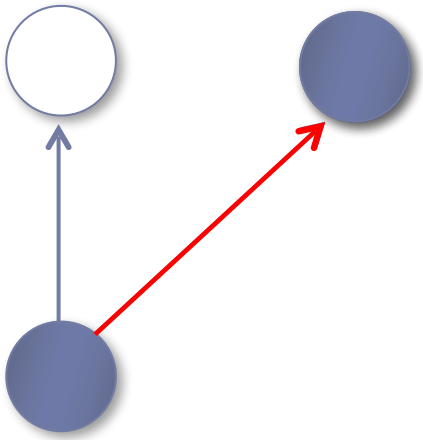
  (*methods for finding optimal [smaller] number of dimensions from which the original data can be reconstructed*)
- 'distance' in semantic space = distance between points on a graph
- distance correlates with e.g. priming and other measures of "semantic overlap".

Elman, 1990

(29 words, 10,000 sentences)

- could we build a system that learns about cooccurrence?
- the mechanism: a ‘blank’ neural network, and some input

Neural networks



Neural networks

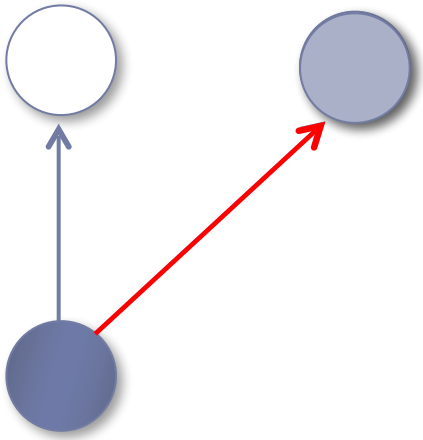
- How they ‘represent’…
  - Patterns of activation

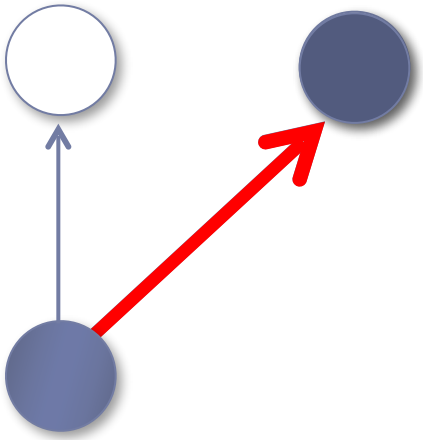
“Cat”

“Dog”

Neural networks

- How they ‘represent’…
  - Patterns of activation
- Spreading Activation

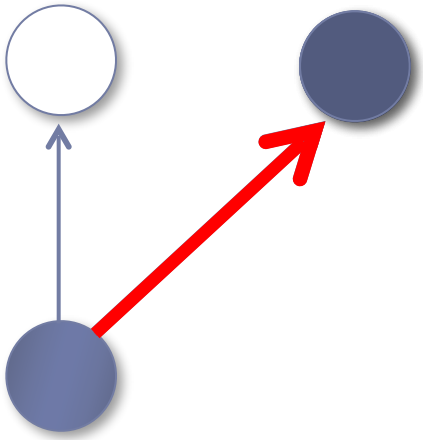


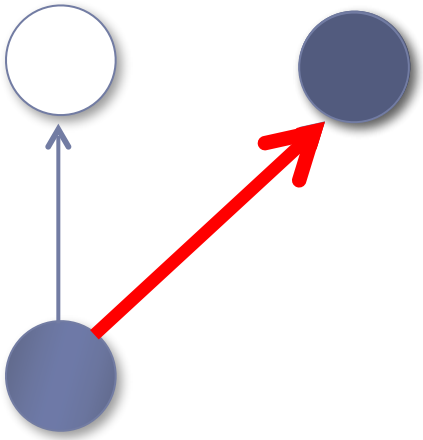


connection strength

Neural networks

- How they ‘represent’…
  - Patterns of activation
- Spreading Activation
- How they learn
  - Adjustment of connection strength





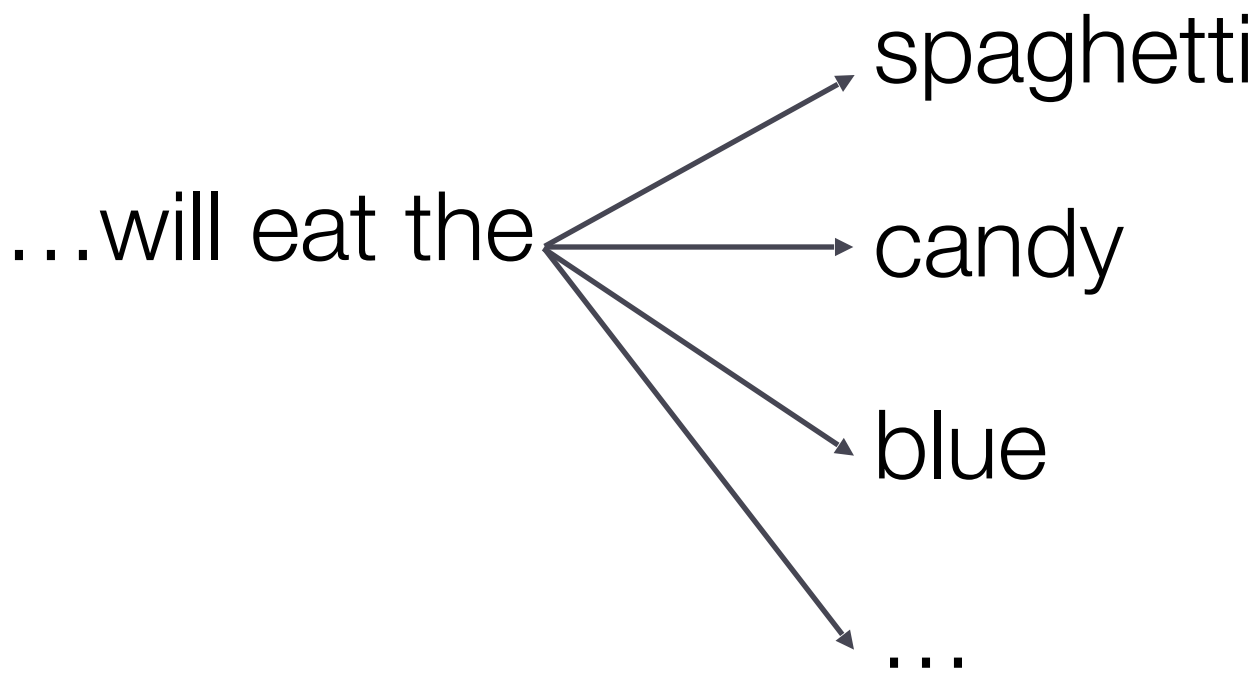
connection strength

Elman, 1990

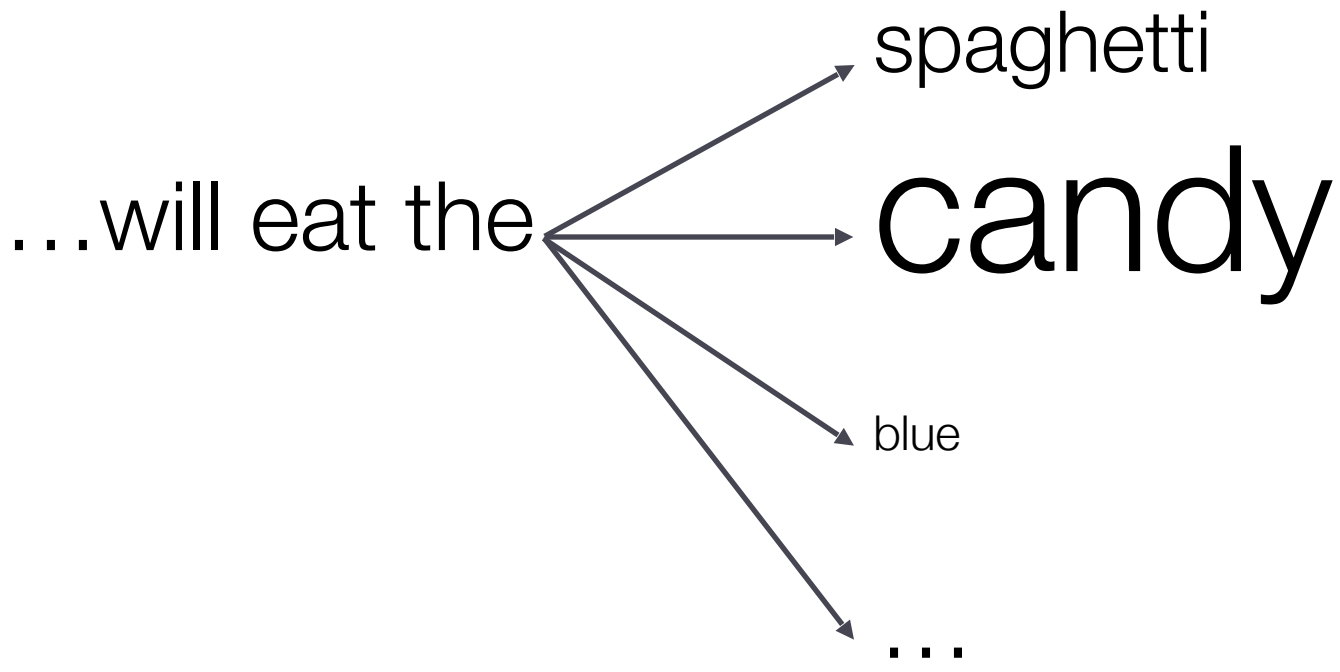
(29 words, 10,000 sentences)

- the mechanism: a ‘blank’ neural network, and some input
  - A “Simple Recurrent Network” (we’re getting there!)
- the task: predict what word will come next
- adjust internal weights to better match the actual next input
  - the model learned that verbs follow nouns, that verbs like ‘eat’ are preceded by animates, and followed by edibles… ‘categories’ ‘emerged’

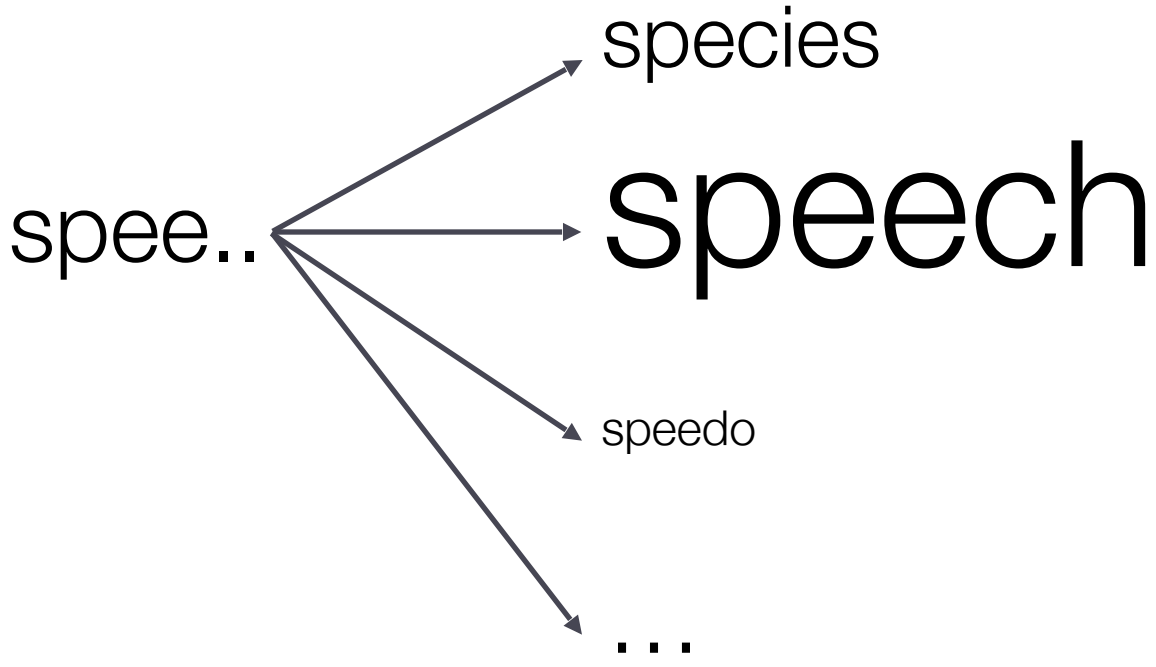
the nature of the prediction



frequency-of-occurrence

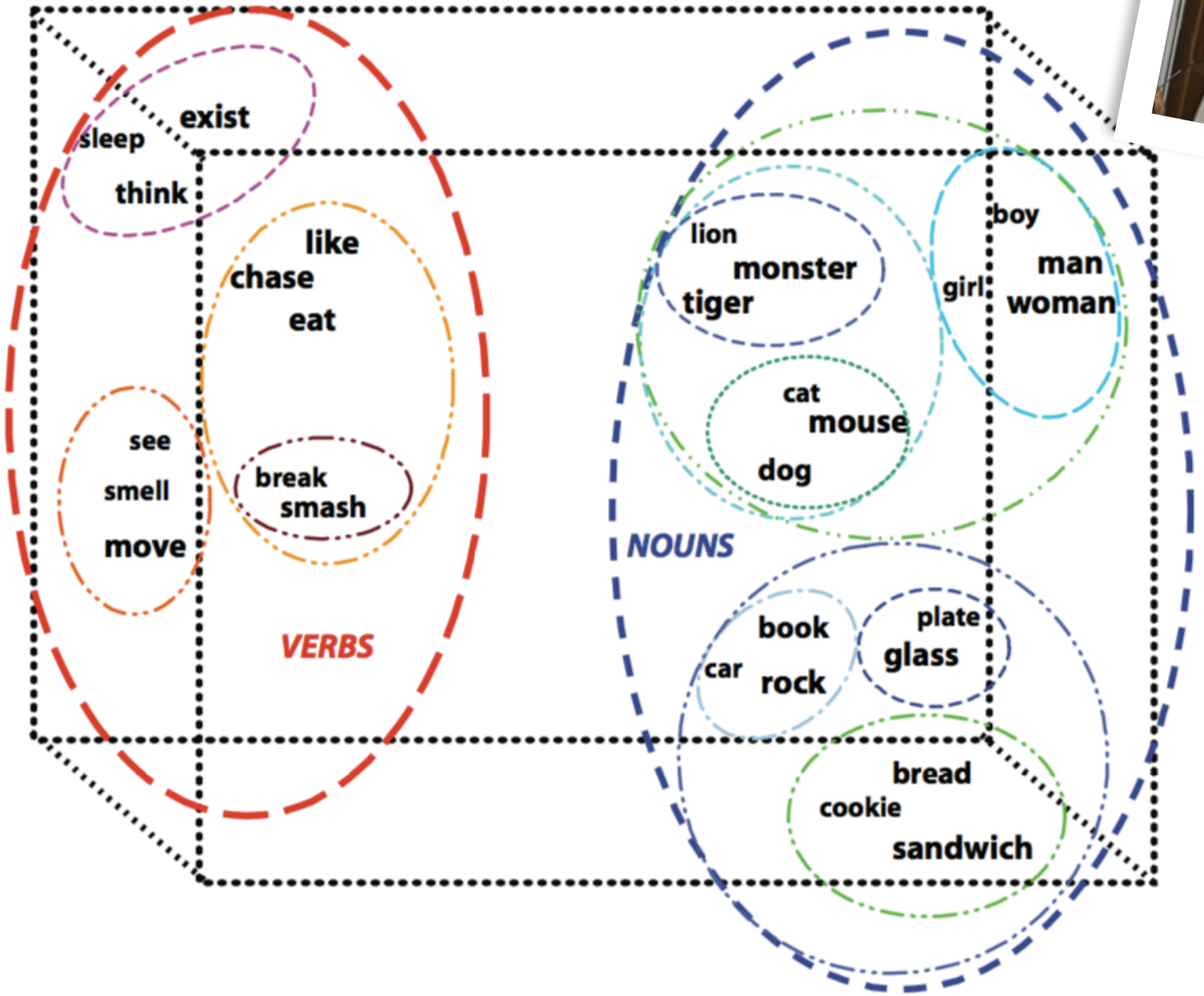


accessing words …frequency



(subsequent work by others)

Emergent representations

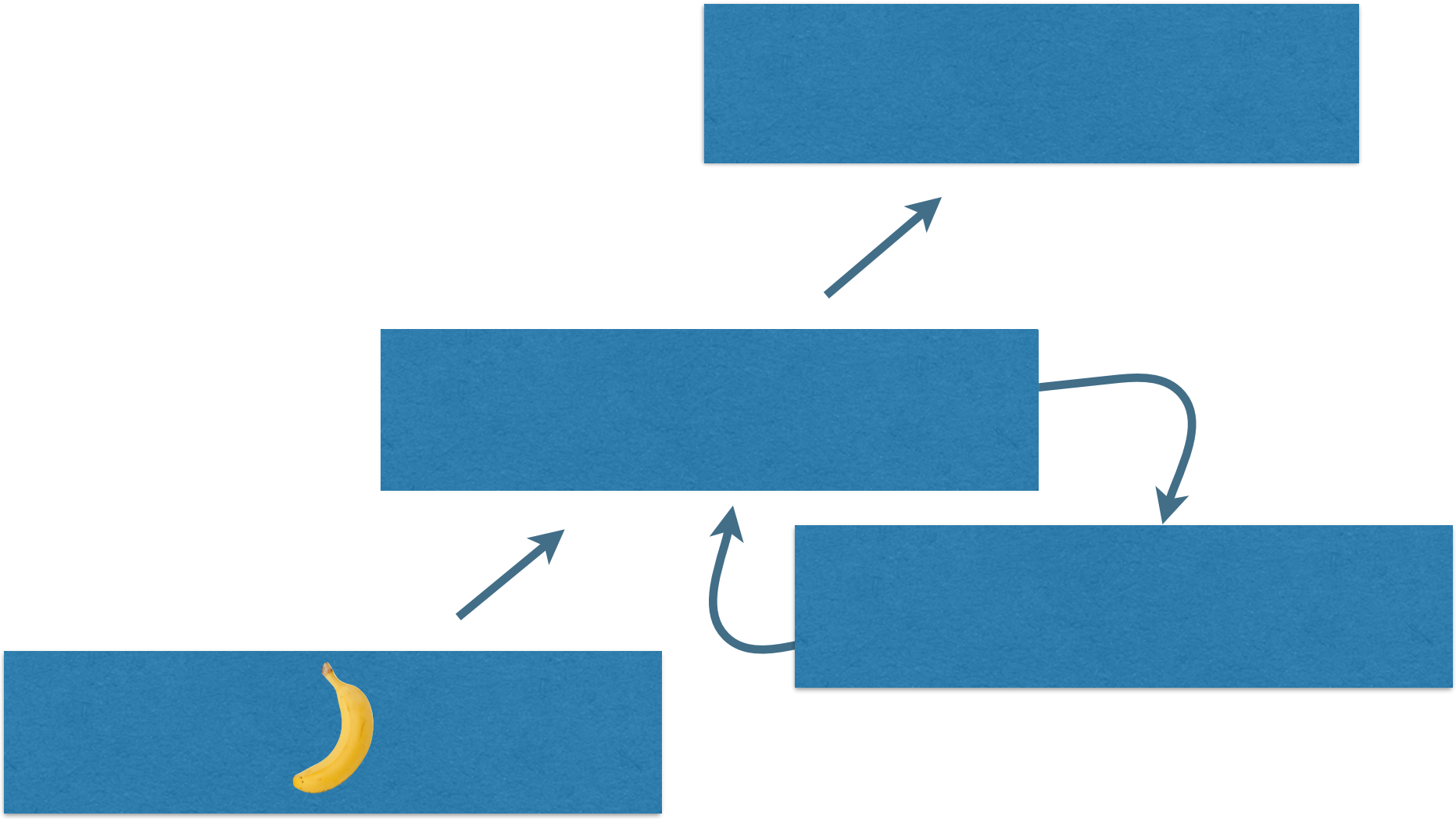


What the SRN learned…

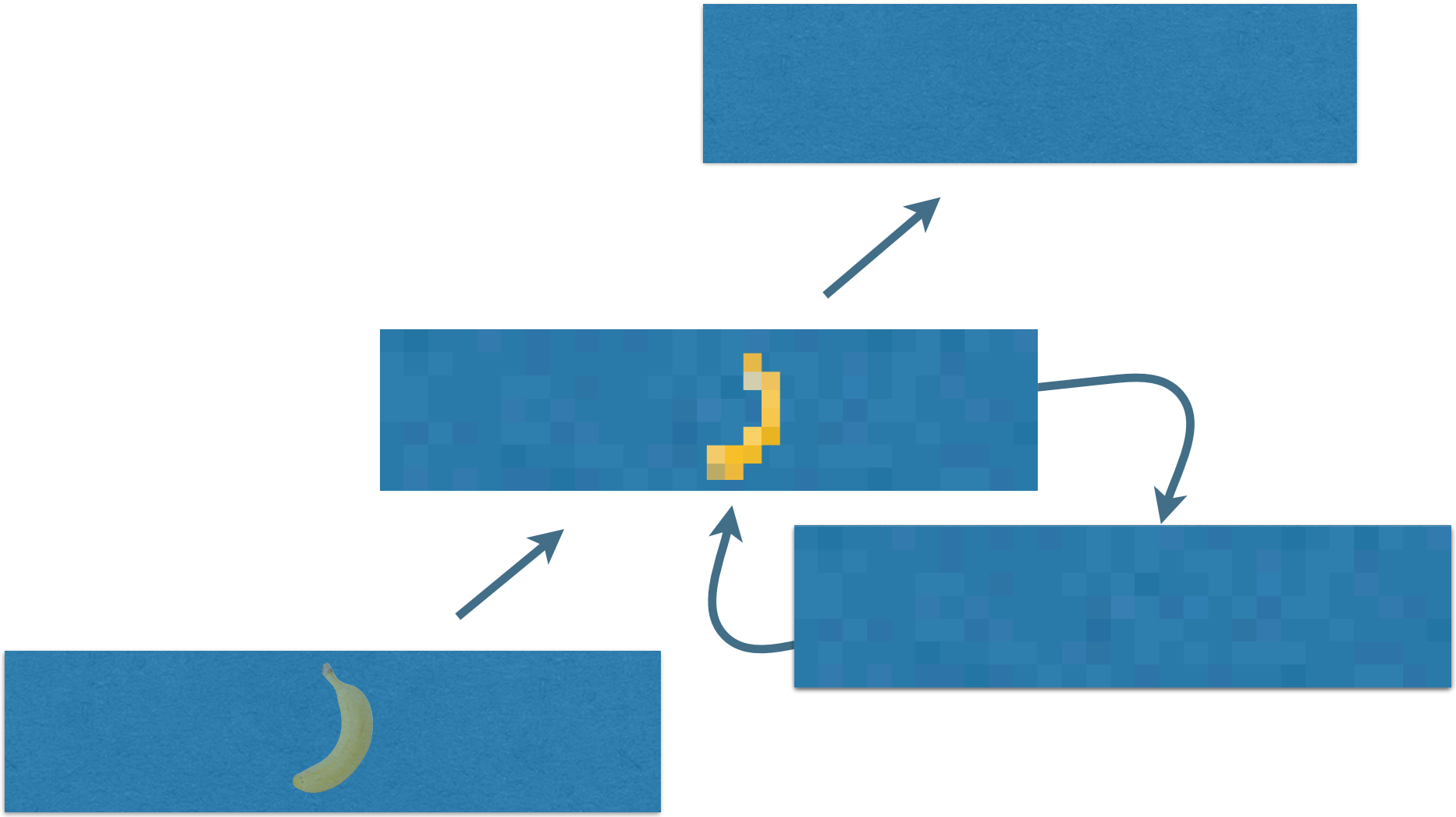
- The SRN learned about the contexts in which words could occur
  - It learned that certain words could occur after certain other words
  - e.g. that what we call ‘verbs’ come after what we call ‘nouns’ (**syntactic knowledge**!) That what we call ‘edible’ things are likely to be mentioned after words like *eat*, or that what we call ‘animate’ things will precede words like *eat* or *chase* (**semantic knowledge**!)**.**
- **This knowledge is referred to as ‘emergent representation’**

How do Recurrent Networks work?

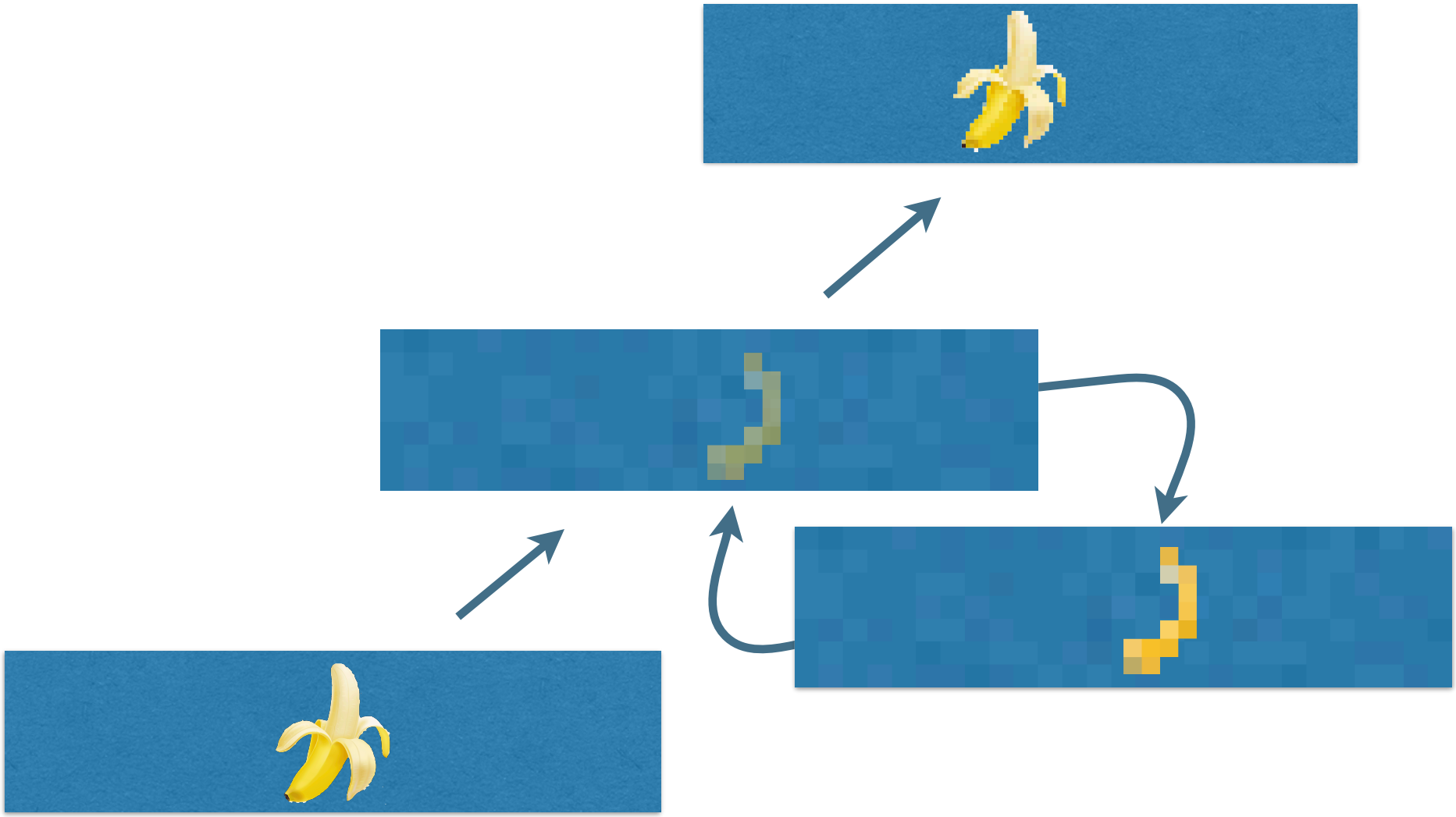
Recurrent neural networks



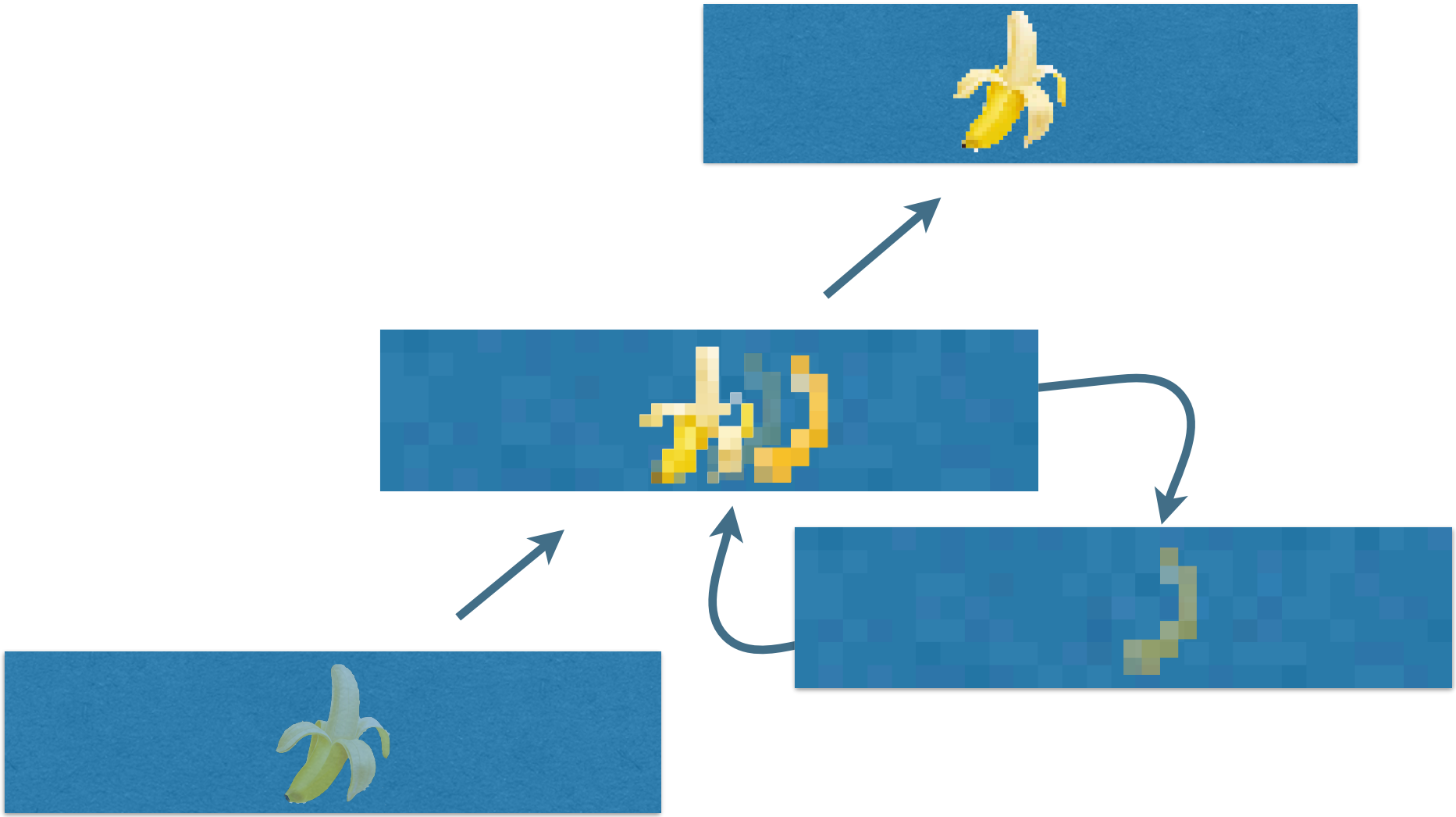
Recurrent neural networks



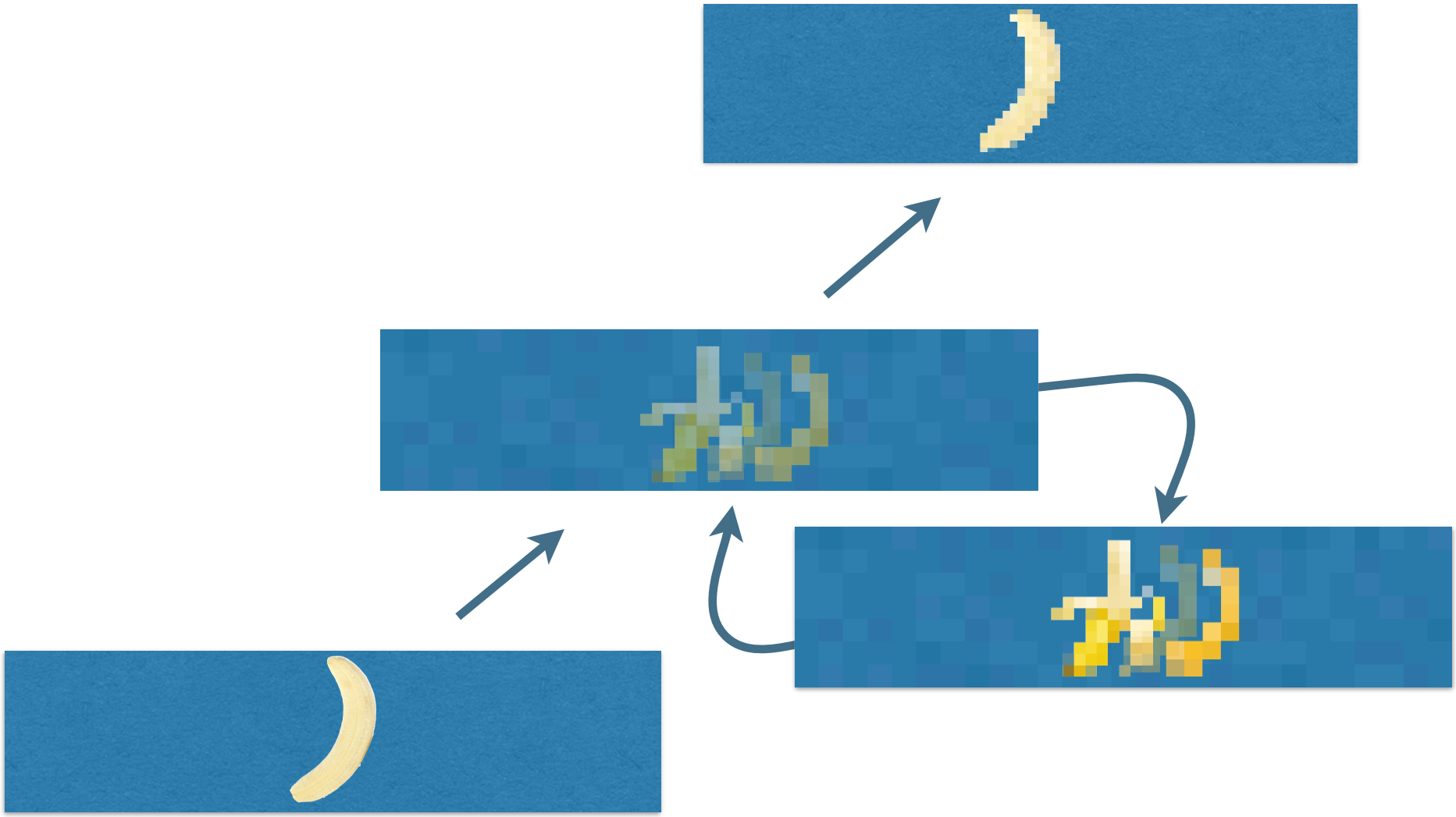
Recurrent neural networks



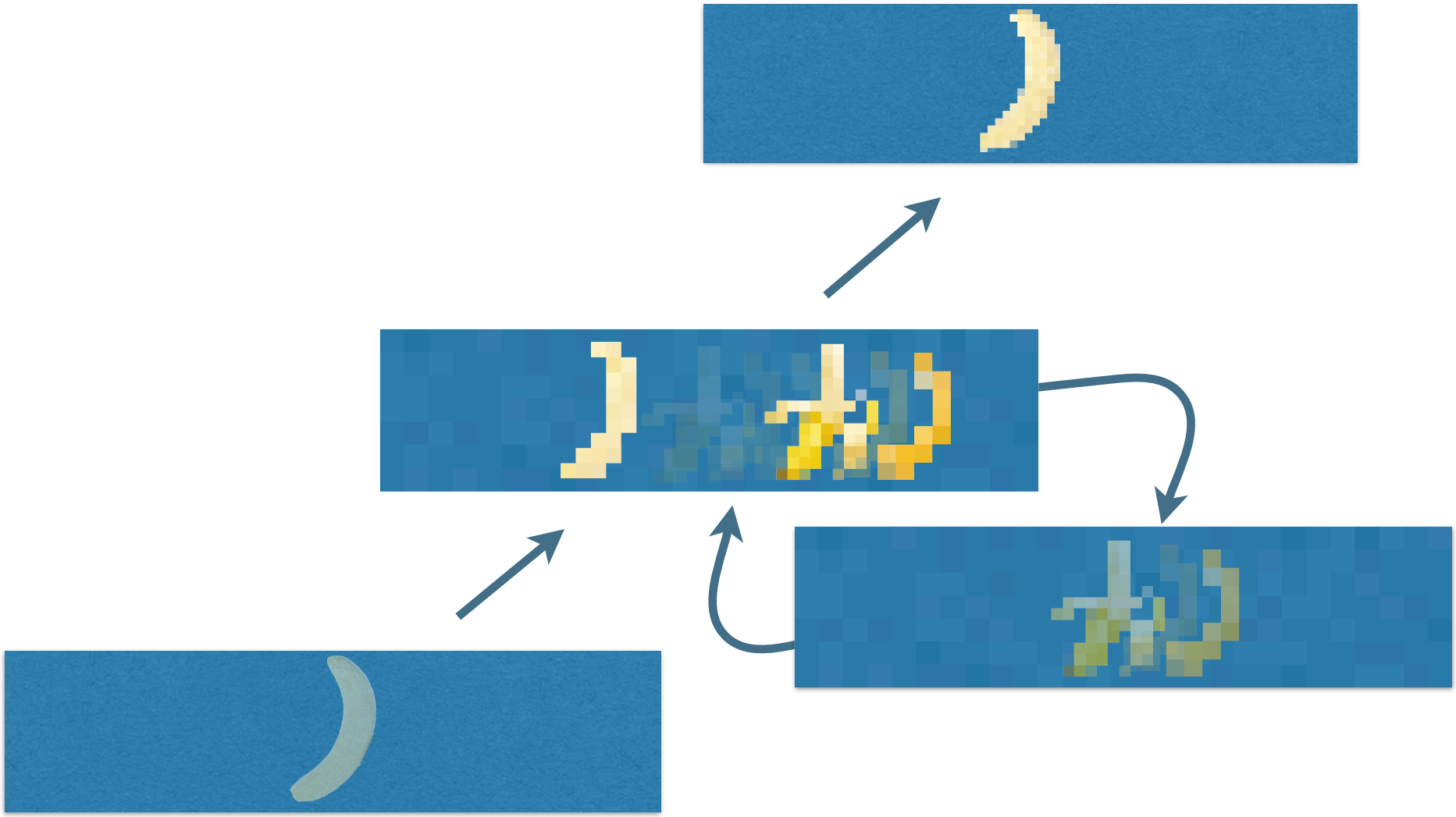
Recurrent neural networks



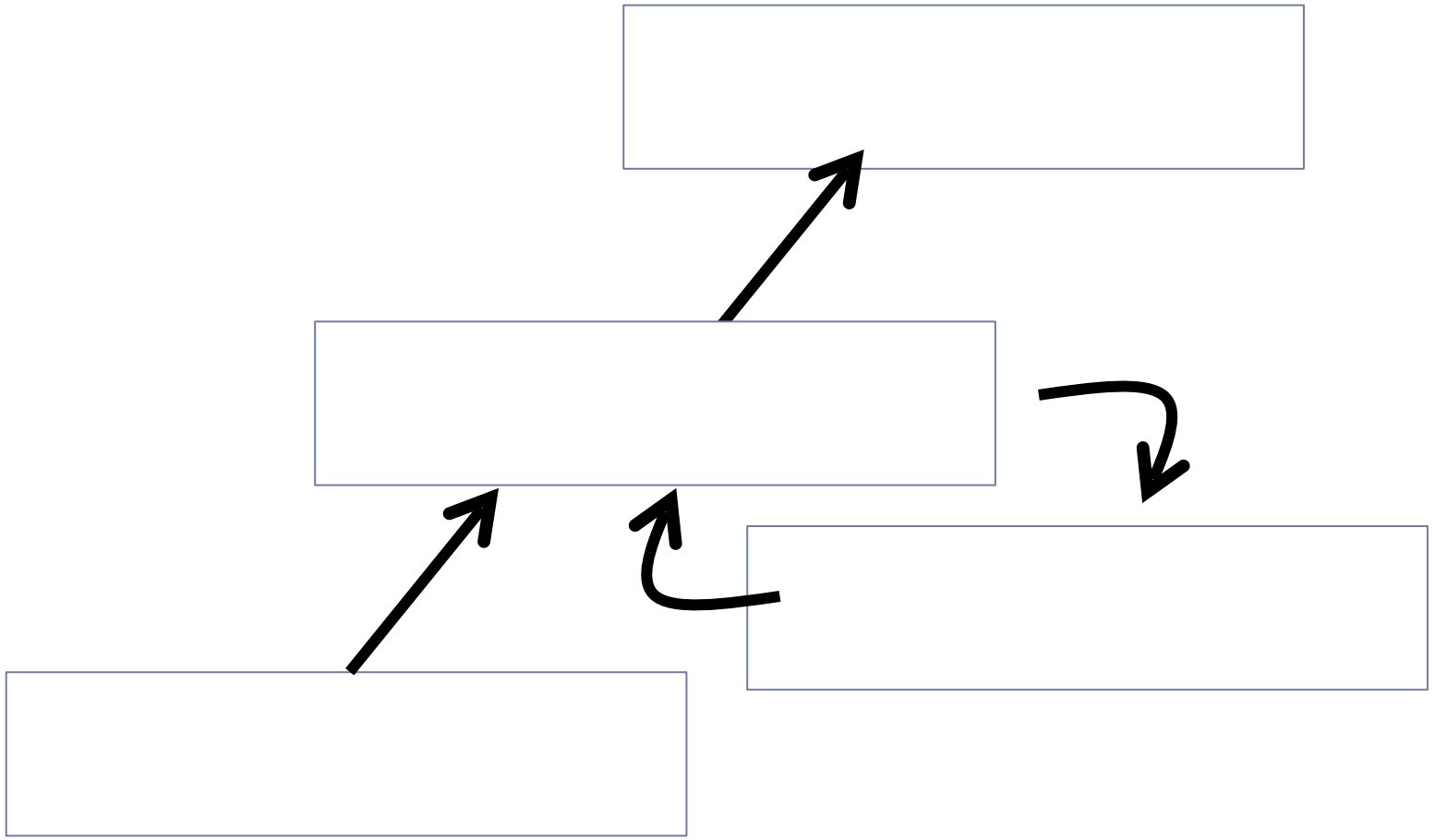
Recurrent neural networks



Recurrent neural networks



Getting the SRN to learn



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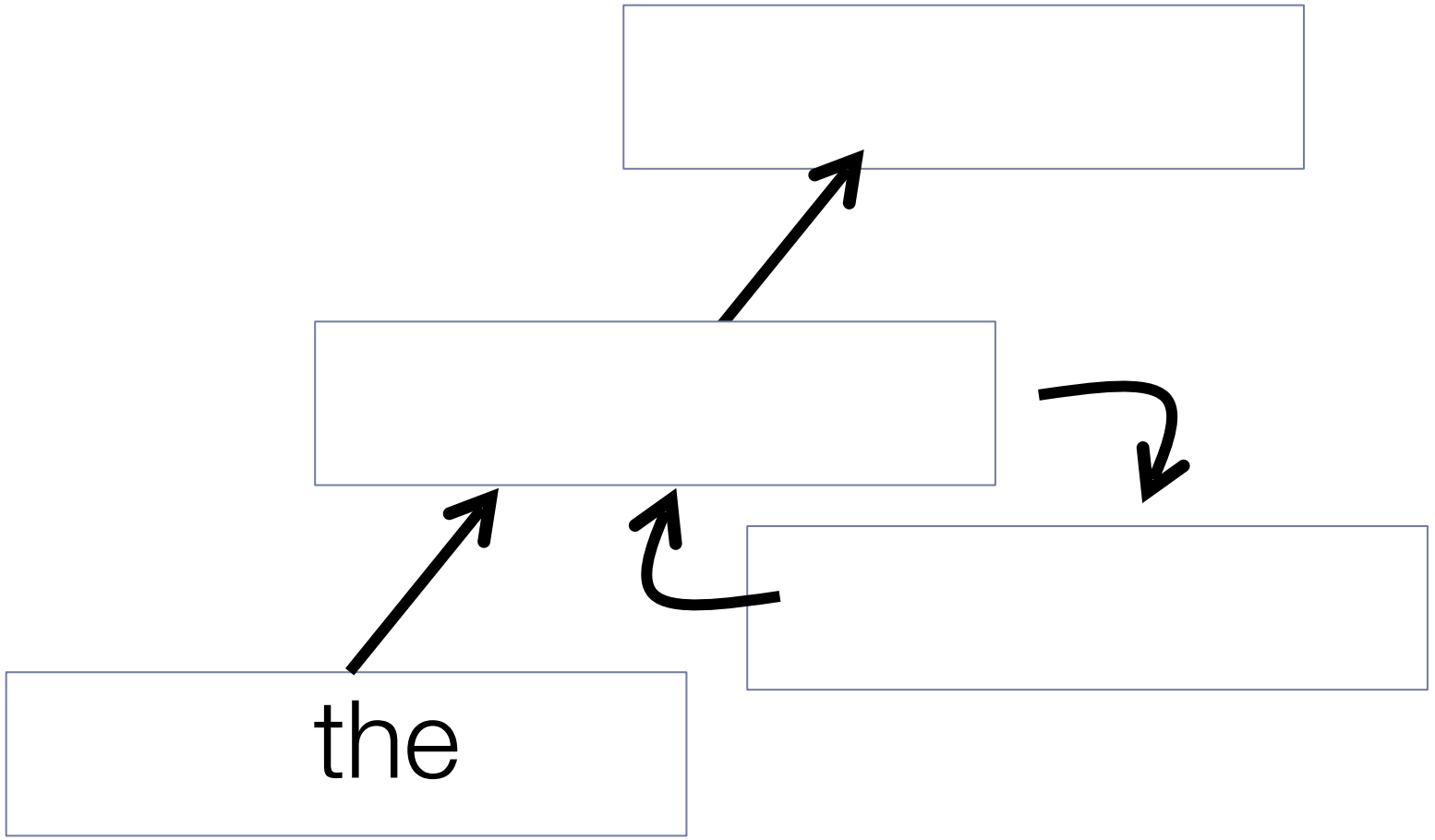

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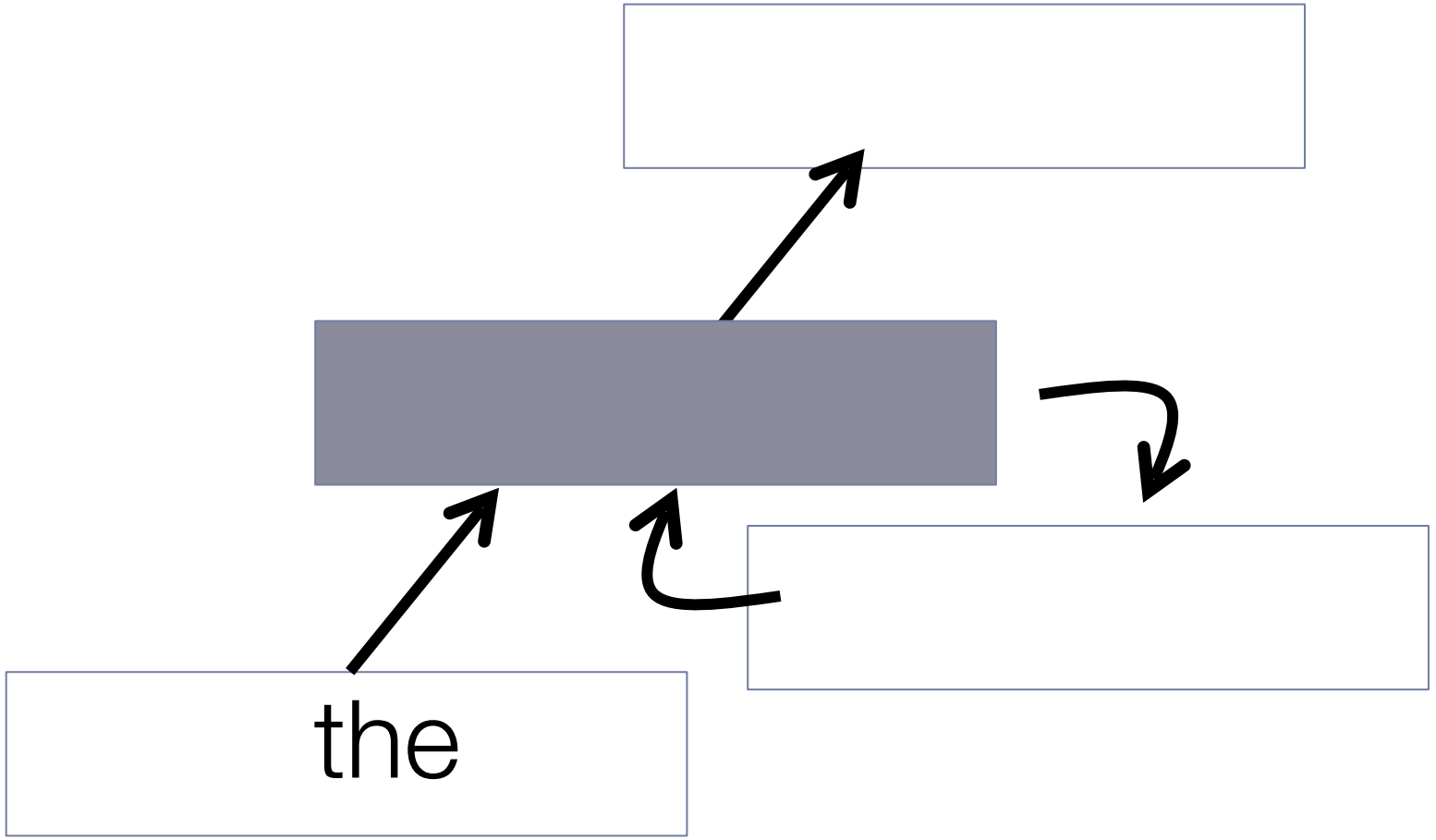

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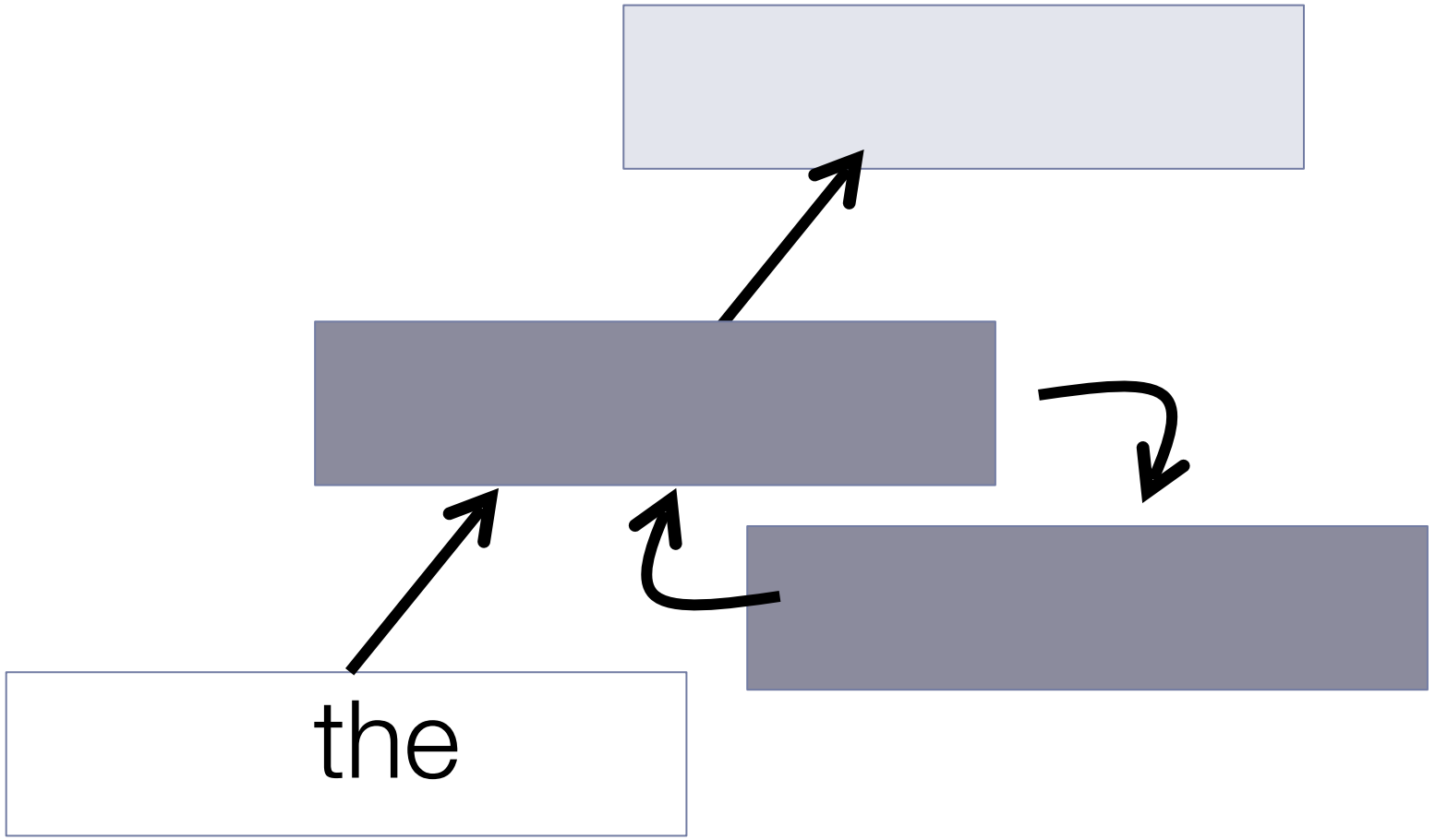

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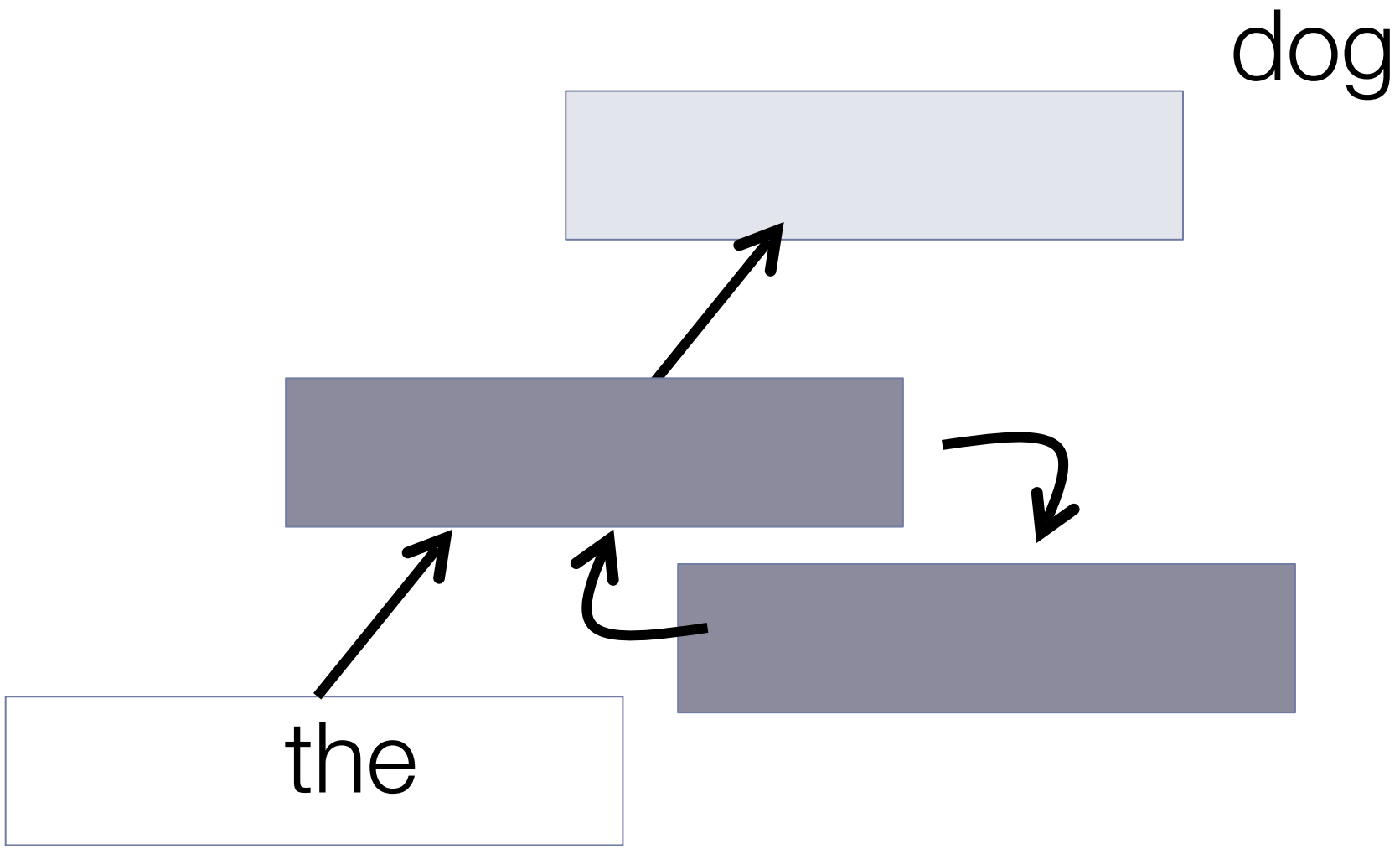

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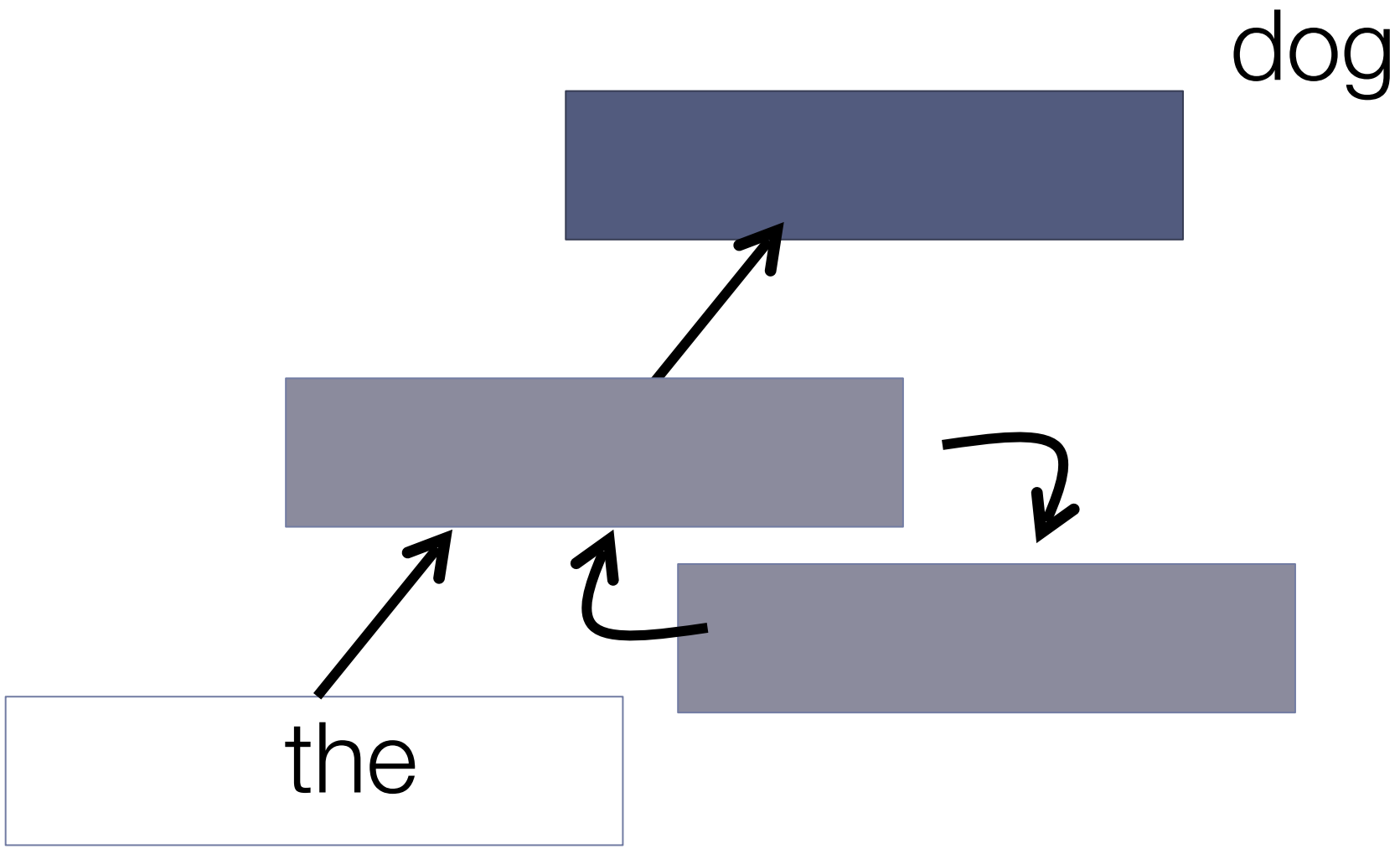

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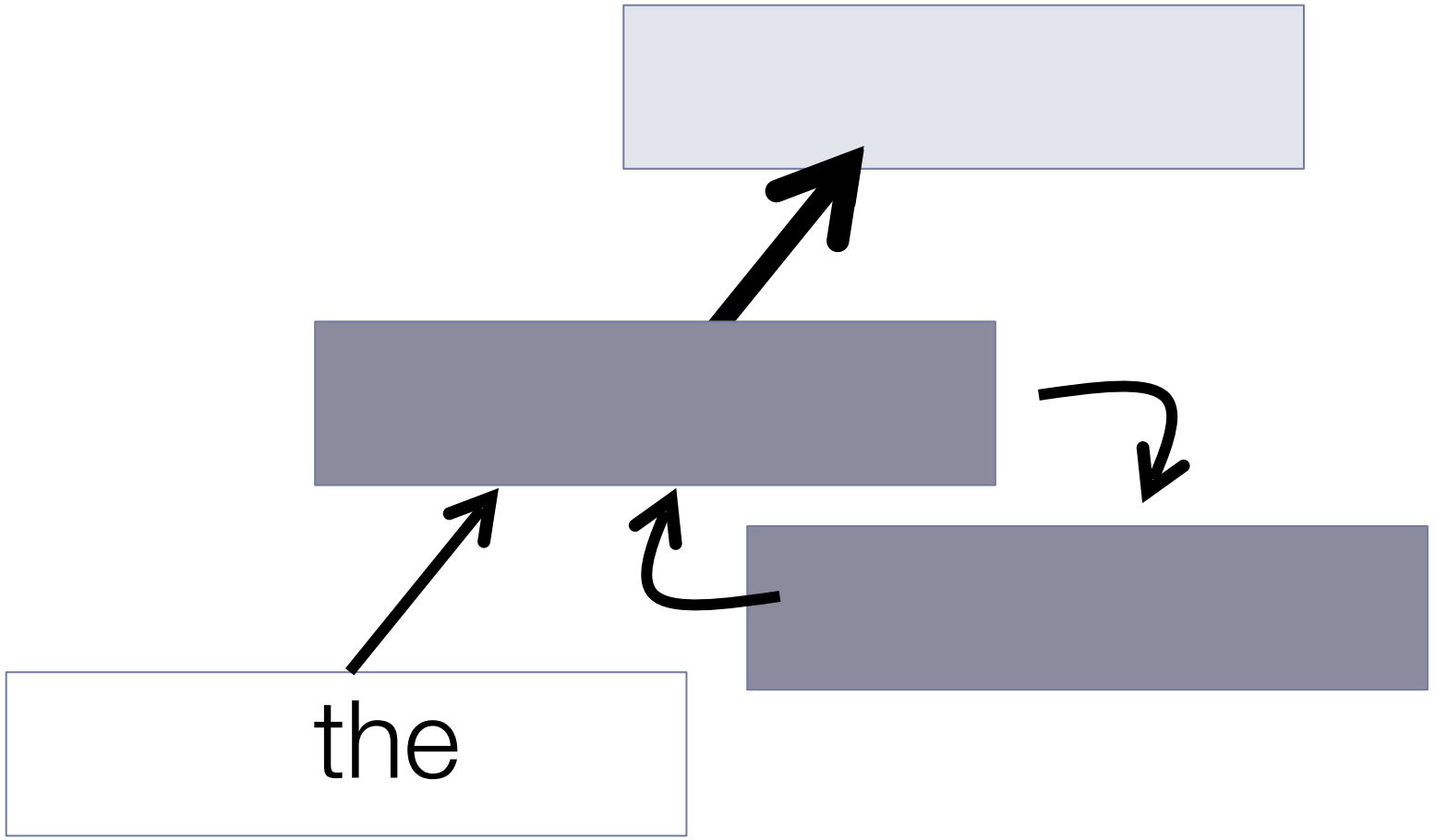
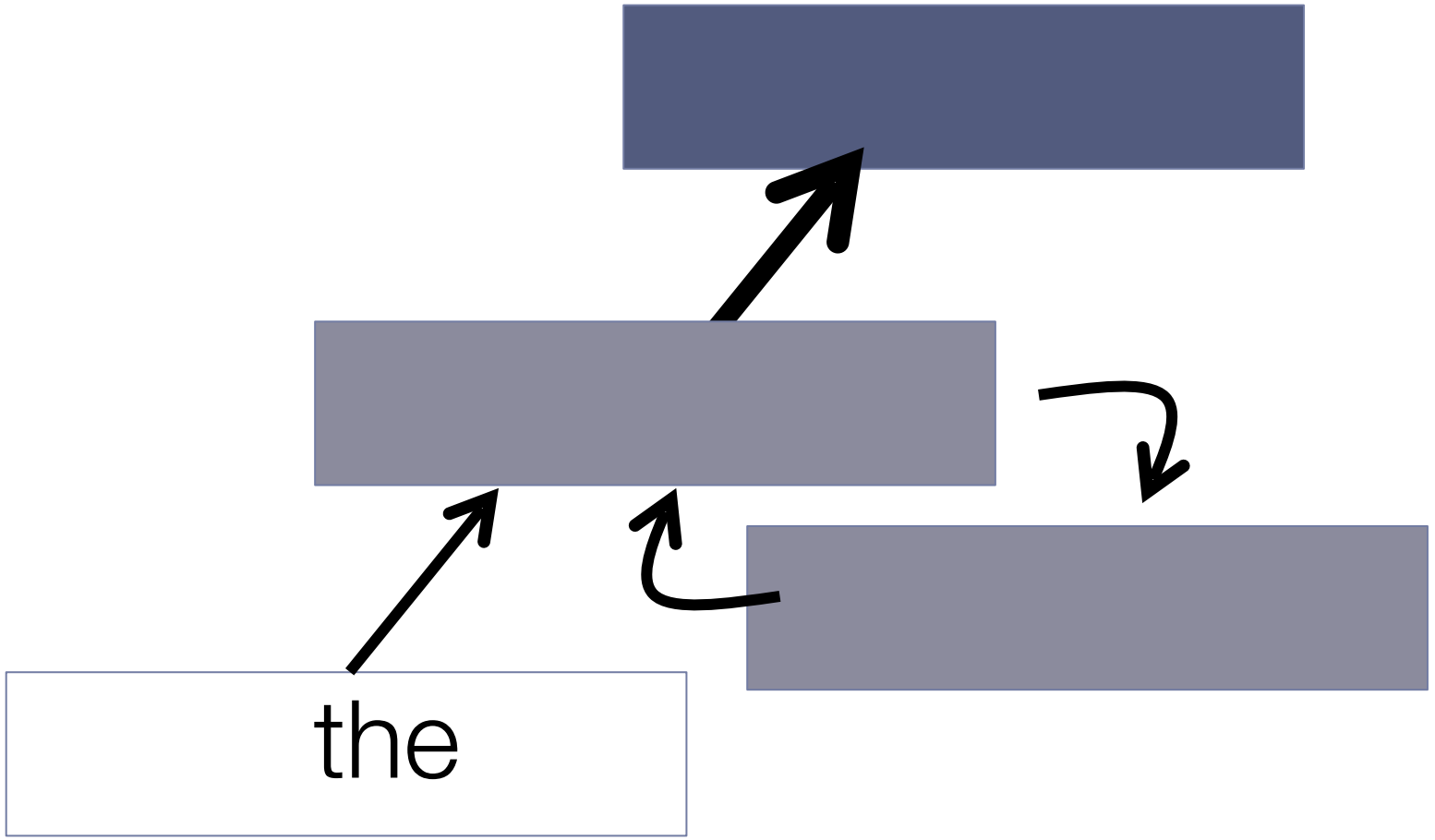
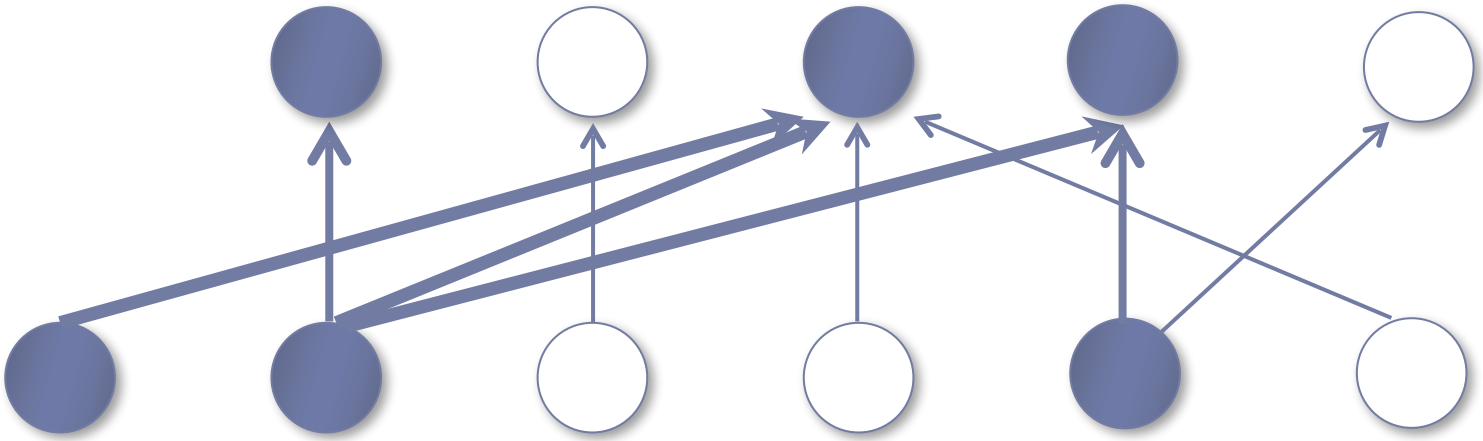


Getting the SRN to learn



Adjusting connection strength

- How they learn
  - Adjustment of connection strength



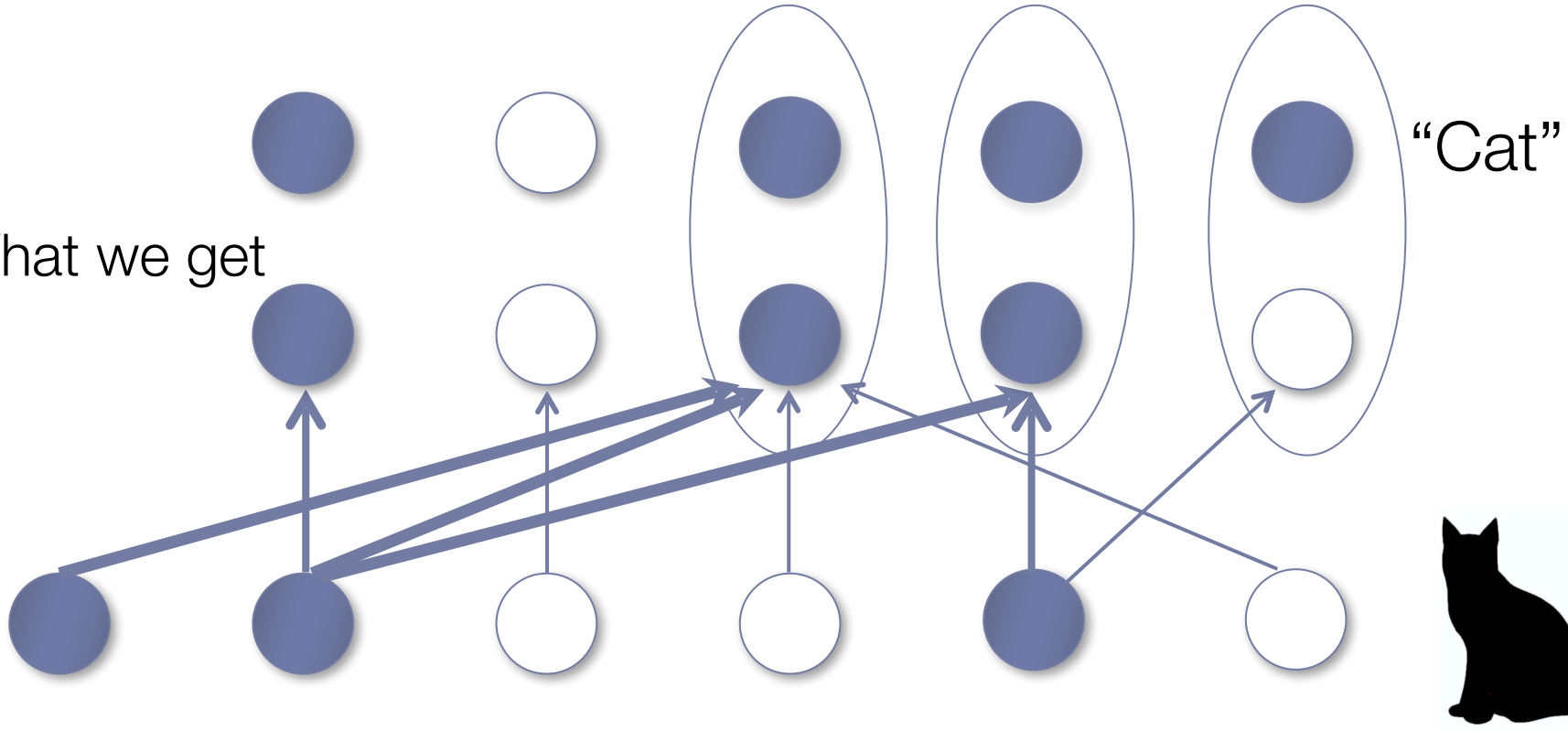
“Cat”

Neural networks

We adjust the connection strengths so that “what we get” is closer to “what we want”

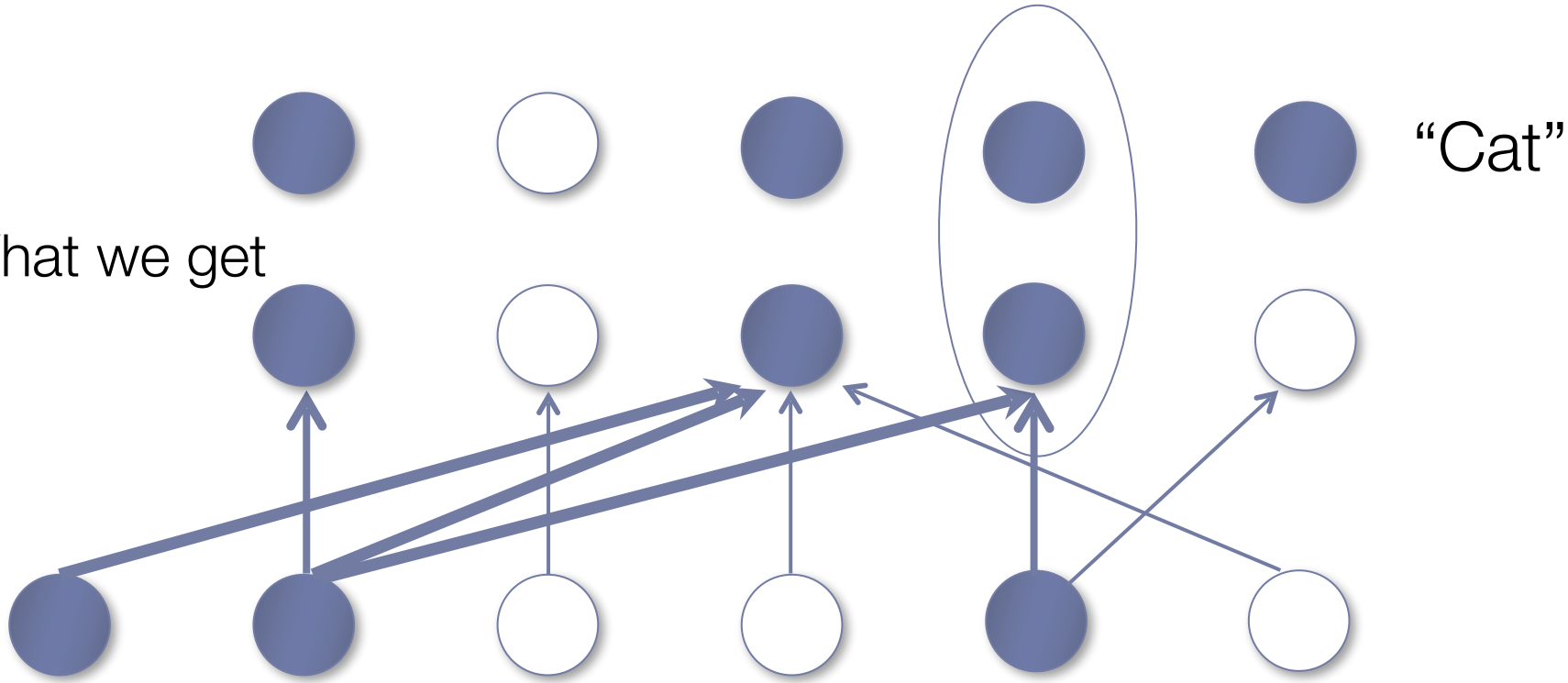
What we want

What we get



Neural networks

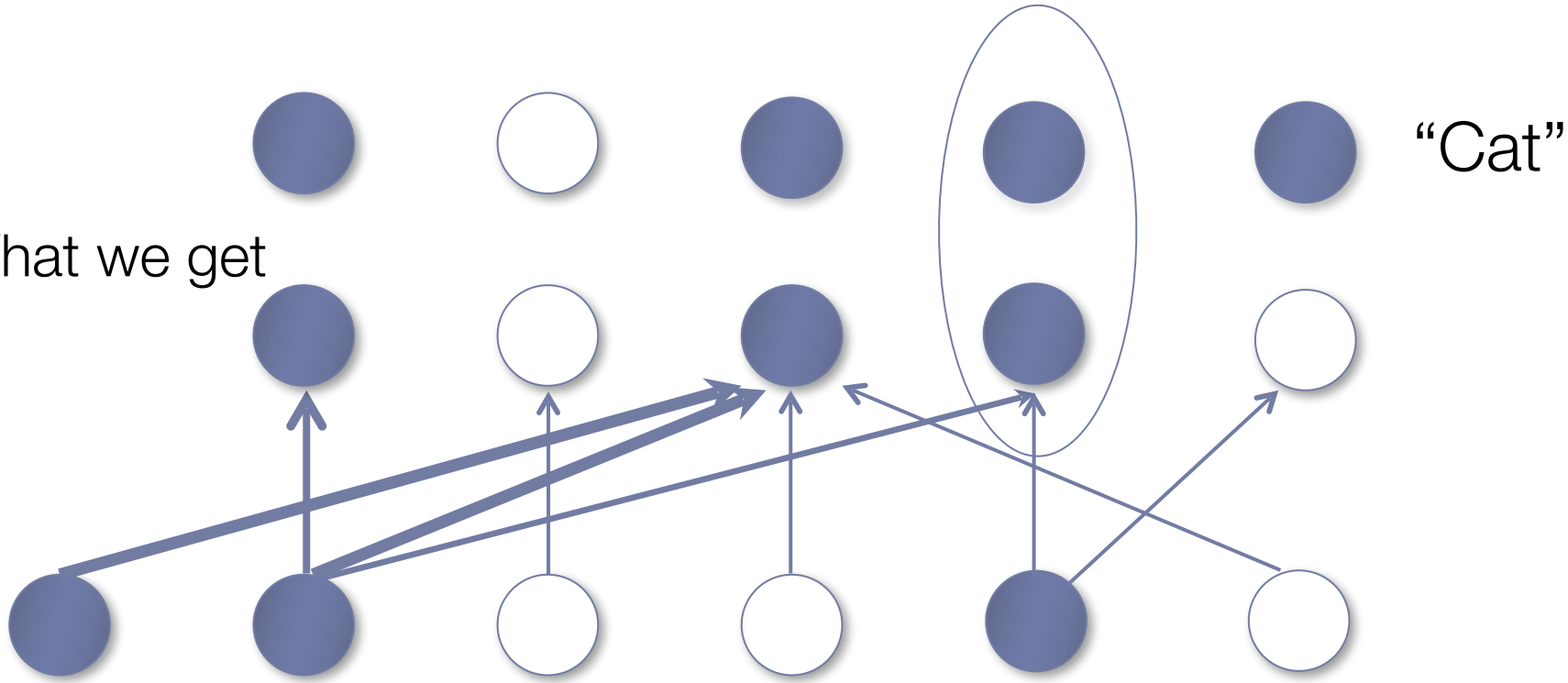
What we want



What we get

Neural networks

What we want

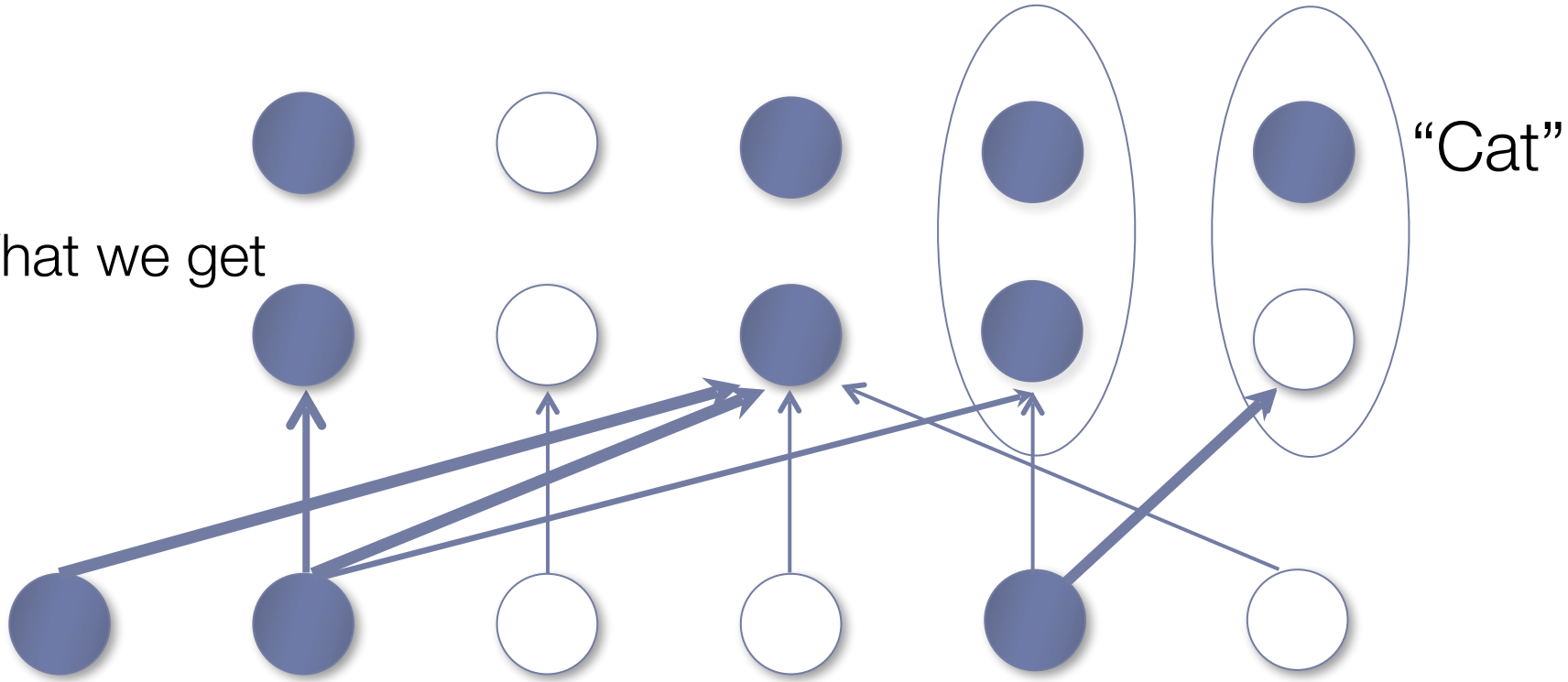


What we get

Neural networks

What we want

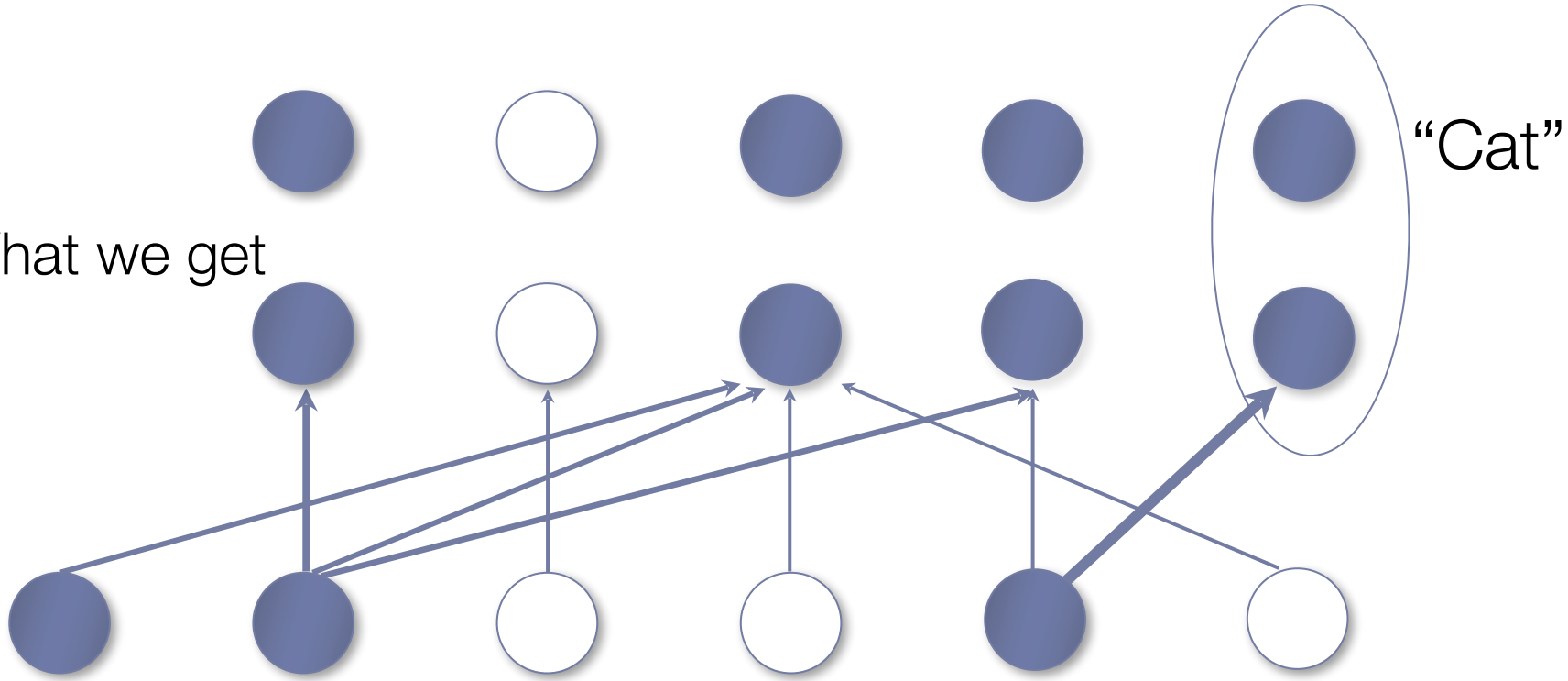
What we get



Neural networks

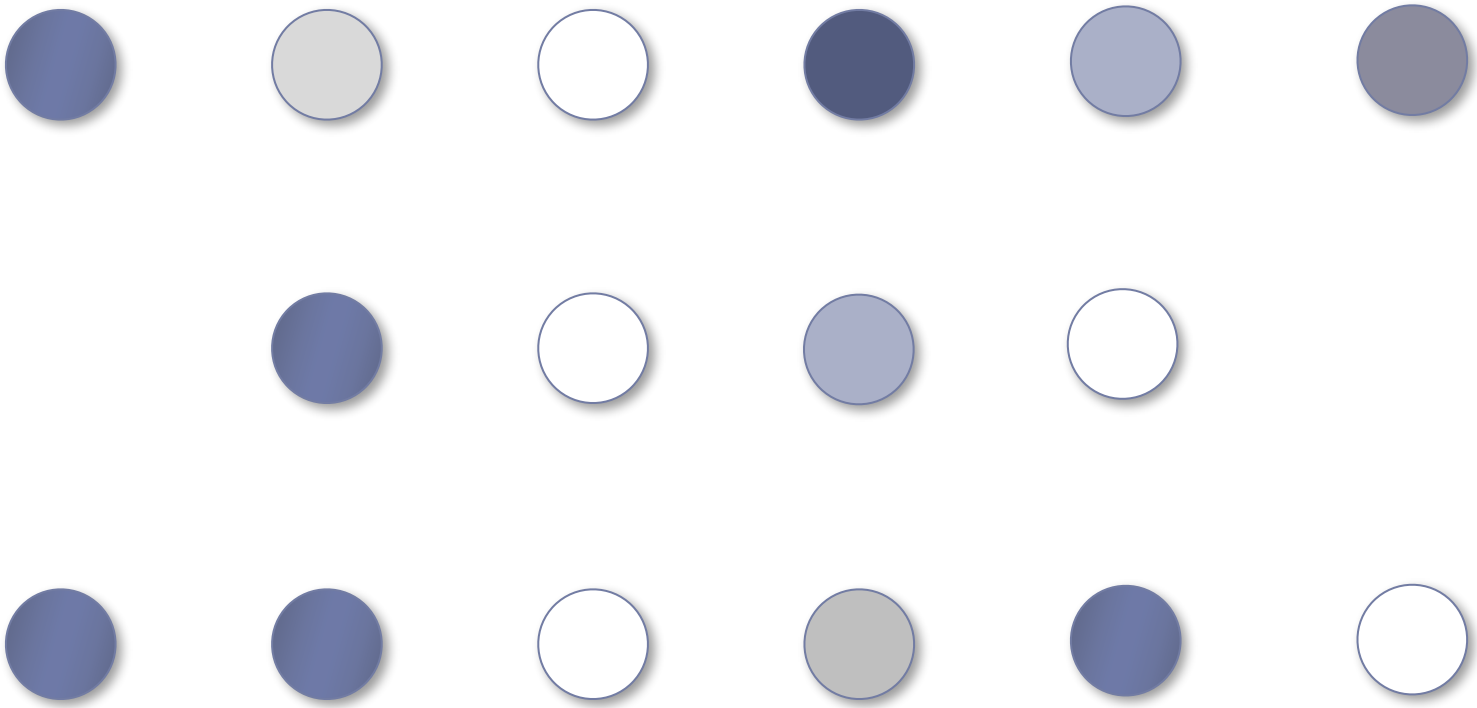
Beware the ‘shower syndrome’

What we want



What we get

“Deep” neural networks (next time)



next time

- learning across layers
  - back propagation
- why backdrop doesn't scale up
- Word2Vec
  - word embeddings
  - negative sampling
  - getting rid of recurrence

- the following week
  - bringing back recurrence
  - why it doesn't scale up
  - using LSTMs and GRUs to enable scaling

- a couple of weeks later
  - getting rid of recurrence (again)
  - Transformers